アジアの統合植生図化
Integrated vegetation mapping of Asia

16255003

平成16年度～平成19年度科学研究費補助金
（基盤研究（A））研究成果報告書

平成20年５月31日

研究代表者　藤　原　一　繪
横浜国立大学　大学院環境情報研究院教授

<はしがき>

「アジアの統合植生図化」の研究は，4カ国11人のメンバーにより進められた。現地調査を中心に，衛星データによる，統一的見解の現存植生図を，広域アジアでまず作成することが第一目的であり，また現地の植生情報を可能な限り蓄積することを目的とした。調査中に，年々自然植生が消失していくことを身にしみて感じている。特に東南アジアでは，近年20年間で大部分の自然林が消失してしまった。植生データは植物の種多様性を示す重要な戸籍簿となっている。アジアの統合植生図では，2003年の衛星写真を基盤に作成された最初の植生図でもある。つい身近に起きたミャンマーのハリケーンによる被害や中国四川省の大地震も，実は緑環境の悪化とも比例している。本植生図をさらに精度を高め，広域な環境変化予測，回復に向けて役立てたいと考えている。

研 究 組 織

研究代表者 ： 藤 原 一 繪 （横浜国立大学大学院環境情報研究院教授）
研究分担者 ： 大 野 啓 一 （横浜国立大学大学院環境情報研究院教授）
研究分担者 ： 持 田 幸 良 （横浜国立大学大学院環境情報研究院教授）
研究分担者 ： 中 村 幸 人 （東京農業大学・地域環境科学部）
研究分担者 ： 建 石 隆 太 郎 （千葉大学・環境リモートセンシング研究センター）
研究分担者 ： 佐 藤 浩 （国土地理院・地理地殻活動研究センター）
研究分担者 ： Box, Elgene O. （*University of Georgia, Athens, Georgia, USA*）
研究分担者 ： Krestov, V. Pavel （*Institute of Biology & Soil Science, Vladivostok, Russia*）
研究分担者 ： 宋 栄昌 （華東師範大学環境科学部）
研究分担者 ： 達 良俊 （華東師範大学環境科学部）
研究分担者 ： 尤 梅海 （徐州師範大学）

交付決定額(配分額)

(金額単位：円)

	直接経費	間接経費	合計
平成16年度	8,300,000	2,490,000	10,790,000
平成17年度	7,700,000	2,310,000	10,010,000
平成18年度	7,400,000	2,220,000	9,620,000
平成19年度	7,400,000	2,220,000	9,620,000
総計	30,800,000	9,240,000	40,040,000

研究発表

1. 雑誌論文

2004 年

Aung, M., Fujiwara, K. and Mochida Y. Phytosociological Study of Mangrove Vegetation in Byone-hmwe Island, Ayeyarwady Delta, Myanmar -Relationship between Floristic Composition and Habitat-, Mangrove Science, (査読有), 3, 2004, 7-23.

Higuchi, M, and Sato, K. A small collection of mosses from Kunashir Island, the Kuriles. Bull. Natn. Sci. Mus., Tokyo, Ser. B(Bot.), (査読無), 30(3), 2004, 103-107.

Kawana Y., Sasamoto H., Mochida Y. and Suzuki K., Leaf protoplast isolation from eight mangrove species of three different families; Avicenniaceae, Rhizophoraceae and Sonneratiaceae. Mangrove Science, (査読有), 3, 2004, 25-31.

Nakamura, Y., H. Nishikawa, Y.C. Song, Y. Murakami, K. Kawano and Wang, X. Syntaxonomical study on wet meadow plant communities in Eastern China, Eco-Habitat, (査読有), 11(1), 2004. 73-84.

Nakamura, Y., Y.C. Song, Y. Murakami, K. Kawano and Wang, X. Syntaxonomical study on beech forest in Eastern China in conparison with Western Japan, Eco-Habitat, (査読有), 11(1), 2004. 105-109.

Nakamura, Y., Y.C. Song, Y.Murakami, K. Kawano and Wang, X. Syntaxonomical study of azonal deciduous and coniferous forests in Eastern China, Eco-Habitat, (査読有), 11(1), 2004. 85-103.

大野勝弘・藤原一繪, ミャンマー国エーヤワディーデルタの主要マングローブ樹種 Heritiera fomes の萌芽特性, Mangrove Science, (査読有), 3, 2004, 33-38.

Sato, H.P.. and Tateishi, R. Land cover classification in Southeast Asia using near and short wave infrared bands, International Journal of Remote Sensing. (査読有), 25, 2004, 2821-2832.

Sato, K. An introduction to vegetation of the Daisetuzan Mountains. Journ. Development Policy Studies of Hokkai-Gakuen Univ., (査読無), 73: 2004, 23-38.

Tateishi, R, and Ebata, M. Analysis of phenologycal change patterns using 1982-2000 Advanced Very High Resolution Radiometer (AVHRR) data, Int. J. of Remote Sensing, (査読有), 25(12), 2004, 2287-2300.

汪正祥・藤原一繪. 中国華中区域におけるブナ林の植生生態学的研究：種組成, 植生構造及び生態類型, 植物地理・分類研究, (査読有), 51(2), 2004, 137-157.

Yun Lei and Ohno, K. Ecological studies on Japanese alder (*Alnus japonica*) forests in Southern Kanto Plain, Central Japan-Syntaxonomy and correlation between the growth. Hikobia, (査読有), 14, 2004, 197-210.

2005年

Javzandulam, T, Tateishi, R, and Sanjaa, T. Analysis of vegetation indices for monitoring vegetation degradation in semi-arid and arid areas of Mongolia, International Journal of Environmental Studies, (査読有), 62(2), 2005, 215-225.

佐藤　浩. アジアの統合植生図化（第1年次）, 平成16年度調査研究年報, 国土地理院技術資料, A・4-No.3, (査読無), 2005, 229-230.

佐藤　浩・建石隆太郎・頼　理沙. 1kmグリッド中国土地利用データを用いたアジアの土地被覆分類における水田のマッピング, 写真測量とリモートセンシング, (査読有), 44(5), 2005, 73-81.

佐藤　謙. アポイ山塊と幌満岳の超塩基性岩植生—偽の永久方形区法によって示された植生変化—, 日本生態学会誌, (査読有), 55, 2005a, 71-83.

汪正祥・藤原一繪・雷耘. 中国の *Fagus lucida* 林と *Fagus engleriana* 林に関する植物社会学的研究, 植物地理・分類研究, (査読有), 53., 2005, 43-65.

2006年

早坂大亮・藤原一繪. 神奈川県湘南海岸に現存する海浜植物群落の成立要因, 日本緑化工学会誌, (査読有), 22(2), 2006, 431-457.

Imai, N., Takyu, M., Nakamura, Y., and Nakamura. T. Gap formation and regeneration of tropical mangrove forests in Ranong, Thailand. Plant Ecology, (査読有), 186(1), 2006, 37-46.

Javzandulam, T, and Tateishi, R, Monitoring vegetation degradation in semi-arid and arid area of Mongolia, Asian Journal of Geoinformatics, (査読有), 6(.2), 2006, 1-10.

Kawanishi, M., Sakio, H., Kubo, M., Shimano, K. and Ohno, K. Effecto of micro-landforms on forest vegetation differentiation and life-form diversity in the Chichibu Mountains, Kanto District,Japan. Vegetation Science, (査読有), 23, 2006, 13-24.

Krestov P.V., Song J.-S., Nakamura Y. and Verkholat V.P. A phytosociological survey of the deciduous temperate forests of mainland Northeast Asia, Phytocoenologia, (査読有), 36(1), 2006, 77-150.

Maung Maung Than, Mochida, Y. and Kogo, M. Survival and growtH.P.erformances of the mangrove species replanted in the ex-agricultural land of the Ayeyarwady delta in Myanmar, Tropics, (査読有), 15(1), 2006, 85-96.

大野啓一. 植物社会学的植生図の利活用と課題－その景観生態学への展開－, 景観生態学, (査読有), 11, 2006, 39-52.

佐藤　浩. アジアの統合植生図化（第2年次）, 平成17年度調査研究年報, 国土地理院技術資料, A・4-No.4, (査読無), 2006, 235-236.

Wang, L., Fujiwara, K., and You, H.M. A vegetetion-ecological study of decieous broad-leaved forests in Heilongjiang Province, China: species composition, structure, disstribution and phytosociological scheme, Hikobia, (査読有), 14, 2006, 431-457.

2007 年

Hayasaka, D., and Fujiwara, K. Habitat differences and spatial distribution patterns of maritime strand forest and adjacent inland forest on subtropical Iriomote Island, Southern Japan, Ecotropica, (査読有), 13, 2007, 121-134.

Kawase, D., Yumoto, T., Hayashi, K., and Sato, K. Molecular phylogenic analysis of the infraspecific taxa of Erigeron thunbergii A. Gray distributed in ultramafic rock sites, Plant Species Biology, (査読有), 22, 2007, 107-115.

Krestov, P. V. and Nakamura, Y. Climatic controls of forest vegetation distribution in Northeast Asia, Ber. d. Reih-Tüxen-Ges, (査読有), 19, 2007, 131-145.

Nakamura, Y. and Krestov, P. V. Biogeographical diversity of alpine tundra vegetation in the oceanic regions of Northeast Asia, Ber. d. Reih-Tüxen-Ges, (査読有), 19, 2007, 117-129.

Nakamura, Y., Krestov P. V., and Omelko, A. Bioclimate and zonal vegetation in Northeast Asia: first approximation to an integrated study, Phytocoenologia, (査読有), 37(3-4), 2007, 443-470.

佐藤　浩. アジアの統合植生図化（第３年次）, 平成 18 年度調査研究年報, 国土地理院技術資料, A・4, (査読無), 2007.

佐藤　浩. アジアの統合植生図化（第４年次）, 平成 19 年度調査研究年報, 国土地理院技術資料, A・4, (査読無), 印刷中.

佐藤　浩. 建石隆太郎, 肖　捷穎, 岩橋純子, 既存のプロジェクトによる土地利用／土地被覆分類データからのグランドトゥルースデータの抽出, 地図, 45(4), (査読有), 2007, 1-16.

Rakhmatuloh, Nitto, D, Hussam Bilbisi, A, Arihara, K, and Tateishi, R. Estimating percent tree cover using regression tree method with very-high-resolution QuickBird images as training data, Journal of the Remote Sensing Society of Japan, (査読有), 27(1), 2007, 1-12.

II. 図書

Box, E.O. and Fujiwara, K. Kluwer Academic Publishers, Vegetation types and their broad-scale distribution, 2004, 106-146.

Sato, K. and Grabherr, G. Daisetsu Gebirge. in C. A. Burga, F. Kloetzli & G. Grabher(eds.) "Gebirge der Erde", 2004, 163-171, Verlag Eugen Ulmer, Germany (in German).

Nakamura, Y. and P. Krestov. Coniferous forests of the Temperate zone of Asia. (Ed. F. Andersson), Ecosystem of the world 6. 2005, 163-220, Elsevier, Amsterdam.

佐藤　謙. 北海道の高山植生、北海道の特殊岩地. (財)日本自然保護協会編・大澤雅彦監修「植物群落モニタリングのすすめ」, 2005b, 219-223, 228-232. 文一総合出版. 東京.

佐藤　謙. 知床の植物、高山植物、保護への提言, 知床博物館編「しれとこライブラリー６知床の植物Ｉ」, 2005c, 142-173, 174-197, 198-213, 北海道新聞社, 札幌.

佐藤　謙. 知床半島と国後島の海岸植物, 知床博物館編「しれとこライブラリー７知床の植物Ⅱ」, 2006, 46-53, 北海道新聞社, 札幌.

石川幸男・佐藤　謙. 知床半島の森林植生. 知床博物館編「しれとこライブラリー７知床の植物Ⅱ」, 2006, 76-112, 北海道新聞社, 札幌.

佐藤　謙. 北海道高山植生誌, 北海道大学出版会, 2007, 688pp.

III. 学会

2004 年

Javzandulam, T, Tateishi, R, and Adel, Sh. Monitoring vegetation degradation in arid and semi-arid area of Mongolia, Proceeding of Indonesia-Japan Joint Scientific Symposium, pp105-108, October 20-22, 2004, Chiba, Japan

Sato, H.P. and Tateishi, R. Estimation on tree cover percentage using TERRA/ASTER data with airborne laser scanning data, International Society of Photogrammetry and Remote Sensing (ISPRS) XXth Congress, July 12-23, 2004, Istanbul, Turkey.

2005 年

Javzandulam, T, and Tateishi, R. Monitoring of biomass changes in arid and semi-arid areas of Mongolia, Proceeding of the 39th conference of the Remote Sensing Society of Japan, Naruto University of Education, Japan, November 24-25, 2005.

Rokhmatuloh, Nitto, D, Al-Bilbisi, H, and Tateishi, R. Percent tree cover estimation using regression tree method: a case study of Africa with very-high resolution QuickBird images as training data, Proc. IGARSS 2005, Jul. 25-29, 2005, Seoul, Korea (DVD ROM).

Sato, H.P., and Sekiguchi, T. Mapping of topography and vegetation in Shirakami Mountains "world heritage natural resources" in Japan, 22nd International Cartographic Conference 2005, July 9-16, 2005, A Coruna, Spain.

2006 年

Fujiwara, K. and Box, E.O. Introduction: Symposium aim and vegetation in Asia. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan.

Krestov, P.V. Integrated vegetation mapping in Asia: Phytosociological lines in Northern Asia. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan.

Mochida, Y. and Maung Maung Than. Mangrove vegetation and ecological characteristics of Southeast Asia for vegetation mapping. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan.

Nakamura, Y. and Krestov, P.V. Classification and its Attributes in northern Asia. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan.

Nakamura, Y., Krestov, P. V., and Sato, K. Classification of Alpine Vegetation and its attributes in Northern Asia, East Asian Federation of Ecological Societies, 2006, Niigata.

Ohno, K., and Song, J.-S. Classification of actual vegetation and landscape in Korea. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan.

Safronova, I. Classification and ecologyical characteristics of steppe vegetation for vegetation mapping. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan.

Sato, H.P., Tateishi, R. and Xiao, J. Paddy ground truth data collection and evaluation for land cover mapping, Annual meeting of the international Society of Optical Engineering, November 13-17, 2006, Panaji, Goa, India.

Song, Y, Fujiwara, K., and Box, E.O. Evergreen broad-leaved forest of Asia. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan.

Tateishi, R. and Sato, H.P. Vegetation cover of Asia discerned from Satellite data. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan.

You, H.-M., Fujiwara, K., Tang, Q. Wang, M. Deciduous oak forests in China and their ecological situation in East Asia. The 2nd EAFES symposium, March 26, 2006, Niigata, Japan

2007 年

Fujiwara, K. Vegetation in Asia-for sustainable management and restoration, Ecological Complexity and Sustainability (Eco Summit 2007), May 25, 2007, Beijing (China).

Hoan, NT, and Tateishi, R. Forest Cover Change in Vietnam period 2000–2004. Japan Society of Remote Sensing Symposium, Proc, 105-106, May, 2007

Krestov, P.V. and Nakamura, Y. Climatic controls of forest vegetation distribution in Northeast Asia, Jahrestagung d. Reih-Tüxen-Ges, April 1, 2007 Rinteln(Germany)

Mochida Y. and Maung Maung Than. Vegetation in Asia - their sustainable managiment and restoration from alpine to urban area - . Mangrove forests in Asia: composition, distributin, disturbance and restoration. Ecological Complexity and Sustainability (Eco Summit 2007), May 25, 2007, Beijing (China).

Nakamura, Y. Japanese vegetation classification system The 5th Conference: Vegetation Diversity of Taiwan, October 6, 2007, Taiwan.

Nakamura, Y. and Krestov, P. V. Biogeographical diversity of alpine tundra vegetation in the oceanic regions of Northeast AsiaJahrestagung d. Reih-Tüxen-Ges, April 1, 2007 Rinteln(Germany)

Nakamura, Y., Sato, K. and Krestov, P. V. Alpine vegetation in Asia and its sustainable management Ecological Complexity and Sustainability ((Eco Summit 2007), May 25, 2007, Beijing (China).

Ohno, K. and Song, J.-S. Landscape-Ecological studies on urban green areas for the sustainable utilizeation, Ecological Complexity and Sustainability (Eco Summit 2007), May 25, 2007, Beijing (China).

Tateishi, R., Sato, H.P., and Xiao, J. Vegetation mapping of Asia using MODIS data, Ecological complexity and Sustainability (Eco Summit 2007), May 21-29, 2007. Beijing, China.

2008 年

小出　大・持田幸良. 太平洋側分布下限域のブナ個体群に与えた 気候変動の影響, 第 55 回日本生態学会全国大会(福岡), 2008 年 3 月 15 日, 福岡.

Krestov, P.V., Omelko, A., and Nakamura, Y. Vegetation and natural habitatas of Kamtchatka, Jahres Tagung d. Reih-Tuexen-Gesellschaft, 2008, Hannover.

Nakamura, Y. Biographical study of Japanese beech forests in different climatic conditions, Jahres Tagung d. Reih-Tuexen-Gesellschaft,2008, Hannover.

中村幸人・Krestov, PV. 東北アジアのコケモモートウヒクラス針葉樹林の組成と分布, 第 55 回日本生態学会全国大会(福岡), 2008 年 3 月 15 日, 福岡

持田幸良・村嶋秀明. 照葉樹林域における微地形単位ごとの夏緑広葉樹二次林の発達の相違,第 55 回日本生態学会全国大会(福岡), 2008 年 3 月 15 日, 福岡.

村中希望・藤原一繪. 山口県周東・大島地区における異なる常緑広葉樹林と二次林の植生学的研究　第 55 回日本生態学会全国大会(福岡), 2008 年 3 月 15 日, 福岡.

佐藤　謙. 北東アジアの高山植生に関する植物地理学的研究, 第 55 回日本生態学会全国大会(福岡), 2008 年 3 月 15 日, 福岡.

塩野貴之・持田幸良. 砂礫地における植生構造と粒度組成の関係 －高山風衝砂礫地・河床・海浜についてー, 第 55 回日本生態学会全国大会(福岡), 2008 年 3 月 15 日, 福岡.

IV. 博士論文

王林. 中国黒竜江省における落葉広葉樹林の植生生態学的研究. 横浜国立大学大学院環境情報学府学位論文(博士). 68pp. +付図(Fig. 1-24), 付表(Tab. -17).

研究成果

研究目的

研究目的は, 期間4年間でアジアの現存植生図を統合し, 共通のコンセンサスの凡例で, 縮尺 1:7,000,000 の植生図を作製することからはじまった. 現在アジアで印刷されている各国の現存植生図は, それぞれの凡例が, 各国の著者により異なっている.それらを, 共通のコンセンサスで, 多くの異なった分野の研究者,行政, 教育関係者が利用可能な情報図を作り上げることを第一の目的として研究が進められた. さらに,現在の気候, 地形, 土壌, 地質, 現在植生を基盤として,人為的影響を停止した際に,理論的に考えられる土地の潜在能力を植生で示した潜在自然植生図を作製することが第 2 の目的とされたが, 現存植生図作成に時間がかかり, 第 1 バージョンが今回できた. ヨーロッパでは各国で作製した現存植生図および自然植生図を,各国統一した共通のコンセンサスの凡例の下で, 各国の植生学者が集合し,植生図及び凡例解説書を 20 年かけて完成させた. さらにロシアが新しい現存植生図をサンクトペテルブルグのコマロフ植物研究所を中心に完成させた. 2003 年, ウラジオストックにおけるアジアの植生シンポジウムにおいて, コマロフ植物研究所の Safronova 博士より, 各国の様々な研究分野の共通のコンセンサスの基盤にたったアジアの統一植生図を, 特に植生学及び植生図研究が進んでいる日本が中心になりまとめて作製しないかという提案により, 本計画が申請された. 幸にも日本学術振興会平成 16 年度～平成 19 年度科学研究費補助金 基盤研究(A)(海外学術調査)に採択され, アジアの統合植生図化が開始した.

研究計画実施

2004 年(平成 16 年度)

1.8 月 1 日～5 日 「アジアの統合植生図化ワークショップ」をロシア国サントペテルスブルグ市コマロフ植物研究所で開催し,日本,中国,ロシア,アメリカの共同研究者により,それぞれの研究紹介と統合植生図についての意見を取り交わした.出席者は日本:藤原,大野,佐藤謙,持田,建石,中国:Song,アメリカ:Box,ロシア:Safronova および研究所所長と研究スタッフである. 2. 7 月サントペテルスブルグ市の周辺, 寒帯南部の常緑針葉樹林, ボルガ川畔カザン市のナラ林, モンゴルとロシアの境界に発達するステップが調査された. 3. 8 月, 中村, Krestov 班は, 東京－新潟－ウラジオストック－カムチャツカ－ウラジオストック－新潟－東京で調査した.冷温帯北部を含むウラジオストックからハンカ湖へ, 大陸度指数の影響増加に沿ったカンバ類－モンゴリナラ林の植生単位的変化と人為的影響による動態的変化を調査した.カムチャツカ半島ではペトロパブロフスクから北上し,北部のクリュチェフスカヤ火山(4750m)山麓に達する約片道 600km の行程で 200 地点に及ぶ植生調査を行った.カムチャツカにおけるバイオームは Mesoboreal zone, Supraboreal zone, Oroborealzone, Cryoroboreal zone に分かれる.また,東部の太平洋沿岸は

霧の多い冷夏と多雪環境下で海洋性型の Oroborealzone が標高を下げて発達する.４．12月，藤原，Box，Song，You は，福州省の大学研究者の協力を得,中国南部福州省の植生調査･現存植生図のチェックを行った.現在中国で出版されている 1:100 万の現存植生図は,福州省地域は全く現実と異なり,初期段階からの作成が必要であることが確認された.人為的影響による低木二次林およびソウシジュの植林のモザイクをどのように示すかが課題である.５．建石と佐藤浩は,対象地域の植生図作成に必要な広域衛星データの整備を行った.データは,2003 年に観測した米国の地球観測衛星 MODIS データを米国地質調査所から入手し,必要な前処理を行った.

2005 年(平成 17 年度)

1.平成 17 年度は横浜国大および千葉大に集合し，統合植生図作成の為の話し合いを持ちながら，各自分担の植生および地域のグランドトルースと，植生調査資料の収集を行った.

1.植生図に関する討議: 第 1 回の集合は，6 月 15 日 横浜国立大学で，代表者藤原，大野，持田，中村，佐藤謙，佐藤浩が会し，それぞれ平成 17 年度の成果および今後の予定，担当地域における問題点を発表・討議した．佐藤浩よりグランドトルース用の衛星データがそれぞれに配分されることが提案された．その後郵便で送られ，現地で確認された．第 2 回は，10 月 15 日～10 月 17 日，札幌において，東京農大に 10 月から平成 18 年 3 月まで滞在する Krestov を同道し，佐藤謙，中村，藤原で札幌周辺の植生を中心に，植生に関してグランドトルースの合意を得た．第 3 回は，平成 18 年 1 月 5 日，来日した Box，Krestov と，藤原，大野，中村，持田が千葉大の建石を訪ね，相観による現存植生図の為の凡例統一を行った．さらに第 4 回 2 月 27 日千葉大に集合し，テキスト地域を選択，植生凡例テキストを全員で作成する合意した．それぞれ担当地域から凡例地を選択，建石に示し，衛星データの配布を得，討議に入った.

2.現地植生調査

1) 6 月中国新疆省植生調査(砂漠および亜高山植生帯)について Song, Da, Box，藤原および地元新疆大学が加わり植生調査した．新疆省の植生図は比較的正しく現地に則していた．2) 8 月 16 日～3 月 21 日中国黒竜江省西北部における調査を You，藤原で行った．多くが二次林で占められていた．3) 8 月 28 日～9 月 8 日極東ロシア(プリモリア地方)を Krestov とそのスタッフ，藤原，佐藤謙により調査した．樹齢 200 年性の自然保護地で中国東部からの植生類似性のデータを得た．その後 8-10 日佐藤が残り，石灰岩地域の植生調査を行い，日本との類似性が強いデータを収集した．4) 9 月 6 日～9 月 15 日 韓国(安東市)を中心に大野および安東大学宋により植生調査が行われた．5) 9 月 10 日～9 月 16 日タイ国パンガ地域からカノム地域のマレー半島の代償植生およびマングローブ林の確認が藤原により行われた．6) 12 月 18 日～12 月 27 日中国湖南省および重慶市を中心とした常緑広葉樹林地域の自然林調査および代償景観確認が Song，Da，Box，藤原および湖南大学が参加し植生調査を行った.

3. 成果発表

平成 18 年 3 月 24 日～28 日新潟で開催の国際会議「東アジア生態学会連合」第２回大会に

おいてシンポジウムを開催，Song，Da，Safronova，Krestov，藤原，大野，中村，建石，佐藤謙が一同に集合，成果発表をした．

2006 年度は現地調査をロシアおよび中国青海省・チベットの高山荒原,ミャンマー北部でおこなった.さらに千葉大におけるワークショップにおいて凡例検討を行い,モデル図を作成した.

2006 年(平成 18 年度)

1. 7 月-8 月: ヤクーツクからオイミャコンに至る永久凍土地帯の Boreal zone から Subarctic zone のダブリアカラマツ針葉樹林帯を植生調査した.対象はダブリアカラマツ林,ハイマツ低木林,氾濫原のカバノキ科低木林,高山植生,高層湿原などであった.植生調査資料は合計 193 となった.サハリン最高標高にあるロパチナ山系と石灰岩からなるバイダ山の植生は,極域の植生と日本の高山・亜高山植生との中間にある地理的位置を反映して,植生地理学的に両者を繋ぐ特徴を示した.それらの結果は,19 年５月２２～２７日に北京で開催される,中国生態学会主催の国際シンポジウム,"Eco Summit 2007"において発表した.2. 9 月: 中国の青海省とチベット自治区の亜高帯から高山帯の植生調査を行った.対象は亜高山帯のモミ属針葉樹林,カバノキ属夏緑広葉樹林,温帯乾燥草原(ステップ),高山風衝草原,塩生地植生,岩角地植生など,気候的極相群落,土地的極相群落を抽出した.3. 北海道の高山植生を植生地理学的にまとめたモノグラフ,「北海道高山植生誌」を公表し,その中でロシアの植物相ならびに植生との比較検討を部分的ではあるが開始した.このモノグラフに示した北海道の植生資料,日本・ロシア両国の既存研究による資料,さらに本研究によって得られたロシアにおける新しい資料との比較検討の公表は,19 年度の課題としている. 4. 12 月: ミャンマー北部の植生タイプ解明調査を行った.ミャンマーの植生タイプはタイ国に類似するが,熱帯林と亜熱帯林が混在するタイプとした森林型が抽出された.また一部に乾燥林も混在しているが,森林残存地と破壊地が隣接し,将来性が憂慮される.

2007 年度

<u>1. 成果発表:</u> 5月24-27日開催の，中国北京におけるEco Summit07において，藤原・Box・Krestov・Da・中村・大野・佐藤(浩)・持田・肖(建石代理)により1日シンポジウムを開催し，アジアの統合植生図と，基盤植生情報の報告を行い，約100人の参加を得た．

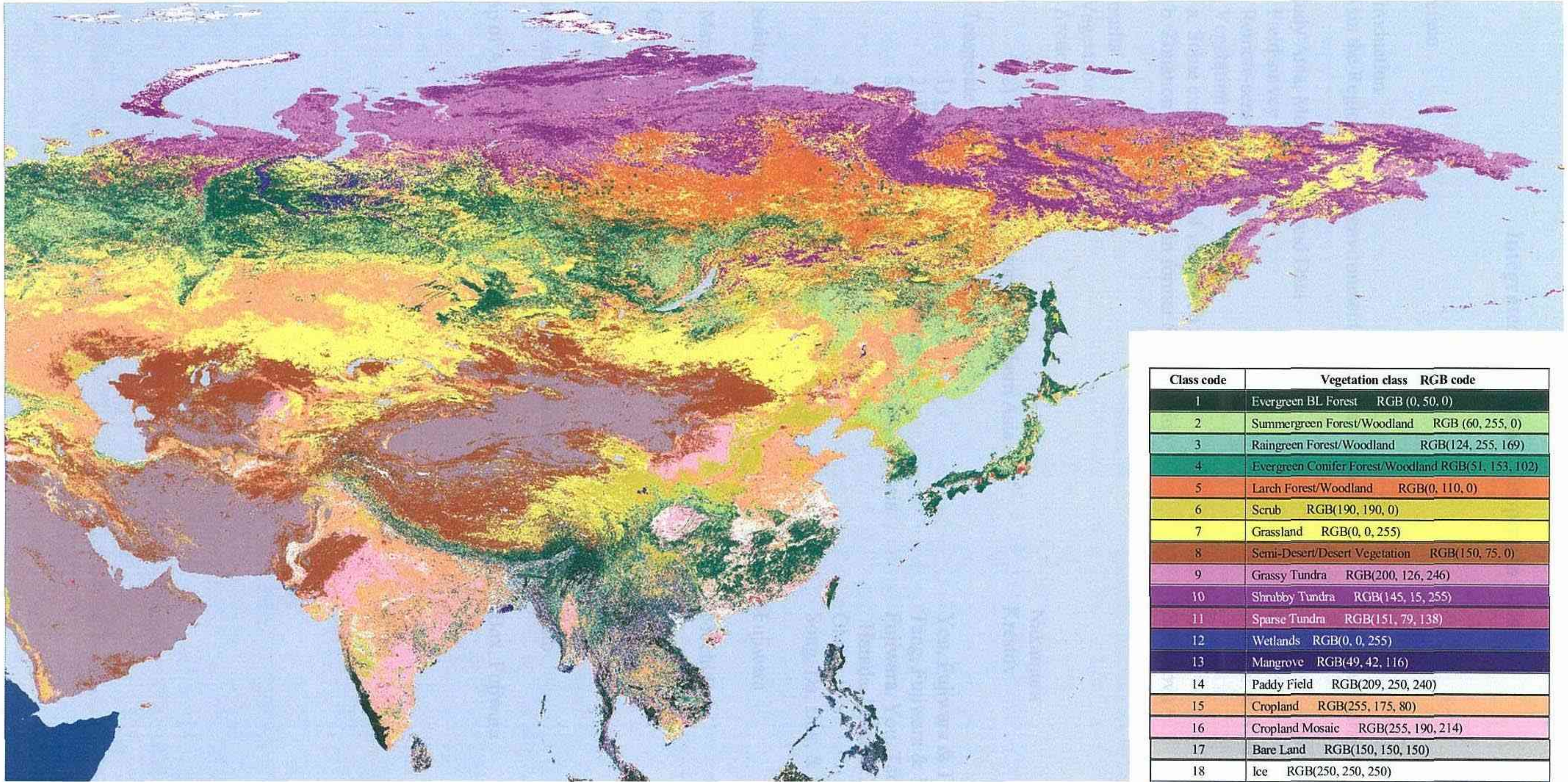
<u>2. 現地調査:</u> 1) 6月-7月ロシア国チェルスキを対象として，寒帯よりツンドラ植生帯のグランドトルースを行った. Krestov, Box，中村・藤原が参加し，チェルスキ研究所のスタッフが協力した．チェルスキではカラマツ林および湿原でおおわれ，カラマツ林の面積が広いことが確認された．二次植生は広い面積を占めない為， 植生図には示されない．北緯69度まで確認した. 2) 7月-8月: Box, Krestov，佐藤謙，クラノヤルスク研究所協力によるロシア国サヤン山地植生情報収集， 3) 8月: Krestov，佐藤謙，中村幸人，藤原，クラノヤルスク研究所協力によるロシア国クラノヤルスク-キジルグランドトルースを行った． 本地域ではカラマツ林よりヨーロッパアカマツ林への移行帯となり，西へ移行することで，カラマツ林がマツ林に変わる. 4) 9月-9月: Krestov，大野畔によるアムール川周辺川辺林確認．アジアでは面積も狭く，殆ど残存しない川辺林情報を，ロシアで収集した. 5) 12月: Box，持田，藤原はラオス大学の協力を得て，ラオス南部を対象としたグランドトルースを行った．低地は開発と利用で自然植生が消失しているが，残存す

る山地常緑広葉樹林まで焼き畑化されている現状であった.
3.ワークショップ 1) 10月に千葉大において，ロシアのKrestov教授を中心にワークショップを開催，第1回討議を行った． 2) その成果を携え，藤原は中国華東師範大学で，中国を中心とした地域の植生図検討を行い，リモートセンシンググループに伝え，さらに3) 11月, 4)12月にワークショップを開催し，植生図の討議を行った.
2007年11月24日-27日：上海華東大学における植生図検討. 宋教授および達教授と藤原で討議，文献との照合を行った. 成果を12月15日のワークショップへ反映した.
2007年11月15日および12月15日：千葉大学におけるワークショップで，植生図を検討した.
以上の成果と国内調査成果をさらに総合的に検討しながら，アジアの統合植生図化と植生情報のまとめを行い，以下にアジアの統合植生図: 現存植生図と，収集データ解析および発表論文を研究報告としてまとめた.

終わりに

4 年間の海外学術研究を振り返り，収集したデータの重みは重要である，後 1 年後，あるいは 10 年後も残っているかわからない植生データを，コツコツ記録し，悪路を走り，山を登り，また時にクマに会い，たき火を囲み討論し，群がり寄る蚊の大群で黒くおおわれながらの調査は，今だからできたのであろう．貴重なデータを印刷・出版し，データベースとして保管したい.
今後，データ整理および，研究報告の拡充を図り，出版助成金によるまとめを行う予定である． さらに現地データ収集を行い，潜在自然植生のまとめに将来発展させたい.

研　究　報　告
Research Report



Class code	Vegetation class RGB code
1	Evergreen BL Forest RGB (0, 50, 0)
2	Summergreen Forest/Woodland RGB (60, 255, 0)
3	Raingreen Forest/Woodland RGB(124, 255, 169)
4	Evergreen Conifer Forest/Woodland RGB(51, 153, 102)
5	Larch Forest/Woodland RGB(0, 110, 0)
6	Scrub RGB(190, 190, 0)
7	Grassland RGB(0, 0, 255)
8	Semi-Desert/Desert Vegetation RGB(150, 75, 0)
9	Grassy Tundra RGB(200, 126, 246)
10	Shrubby Tundra RGB(145, 15, 255)
11	Sparse Tundra RGB(151, 79, 138)
12	Wetlands RGB(0, 0, 255)
13	Mangrove RGB(49, 42, 116)
14	Paddy Field RGB(209, 250, 240)
15	Cropland RGB(255, 175, 80)
16	Cropland Mosaic RGB(255, 190, 214)
17	Bare Land RGB(150, 150, 150)
18	Ice RGB(250, 250, 250)
19	Water RGB(175, 210, 240)
20	Urban RGB(255, 0, 0)

Vegetation map (color version 4)

Integrated Vegetation Mapping in Asia

Preface

When European vegetation map appeared in 1997 at the 40^{th} IAVS (International Vegetation Science) symposium at Ceske Budejovice in Czech Republic, I was shocked to see it. The map was natural vegetation map, but it was integrated whole Europe. Many scientists from whole European countries gathered and they had discussed long time. I was thinking whether we can make an integrated map in whole Asia. We do not have enough vegetation scientists in each country in Asia. How we can make it? It was my question.

When we had an international symposium in Vladivostok in 2003, Dr. Irina Safronova showed a large map of whole Russia based on natural vegetation. Then She suggested for us to make an integrated vegetation map in whole Asia. It was my dream and I talked with Japanese vegetation scientists in this project to think an integrated vegetation map.

Everybody wondered that we can make in limited years. Fortunately one friend of Prof. Yukito Nakamura, Dr. Pavel Krestov, had good experience and work in the field with him. He offered Far East Russia. Dr. Irina Safronova responses western part of Asian Russia. Unfortunately Dr. Nikorai Ermakov could not attend field work, but gave us information in central Asian Russia.

We had great Prof. Yong-Chan Song and young Prof. Liangjun Da in China. We are including Prof. Elgene Box from USA with his global eyes and experiences to work with Dr. H. Walter who described 'Vegetation of world and ecological systems of the geo-biosphere. For the vegetation mapping, we include remote sensing scientists to know actual green environment based on vegetation types. The first color page shows the first draft of integrated vegetation map of Asia. It shows most of lowland area as well as mountain area of China, Japan and Korea lost natural vegetation and somewhat we still have nature in farther high latitude area in Russia.

Even so, we still could not classified mowing grassland or step, and natural or secondary deciduous forests. Especially European scientists could classified deciduous forest types in Europe based on Satellite data in late 1990's already. I hope we can classify these vegetation types next time.

Now we understand how we lost natural vegetation in Asia.

Next target is to make a map of potential natural vegetation. We had important field data all of the Asia even not enough are we have. These area should be kept in next century and to keep record for biodiversity (species richness).

At the last, I would like to say many thanks for our cooperative scientists: Prof. Elgene O. Box to edit English of whole manuscripts, and Prof. Yong-Chan Song, Prof. Liangjun Da, Prof. Pavel V. Krestov, Dr. Irina Safronova, Assc. Prof. You, H.-M. for field work and manuscripts, and my co-workers: Prof. Yukito Nakamura, Prof. Ken Sato, Prof. R. Tateishi, Dr. Hiroshi Sato, Prof. Yukira Mochida, and Prof. Keiichi Ohno.

I also thank for many coworkers in Russia, Korea, China, Laos, Thailand, and Myanmar.

Project leader
Kazue Fujiwara
May 31, 2008

I. Asia the Region: Natural Environment and Human Impacts

Elgene O. Box (*Department of Geography, University of Georgia, Athens, Georgia, USA*)

Kazue Fujiwara (*Graduate School of Environment and Information Scienses, Yokohama National University*)

Unlike other continents, Asia is defined not only by geological boundaries but also by a traditional, cultural separation of Europe and Asia, which share the same Eurasian land mass. Even so, Asia is the world's largest continent and extends almost halfway around the world, from a small western coastline on the Mediterranean Sea (about 25°E in Turkey) eastward to the Bering Strait (166°W) separating it from Alaska. Asia also spans almost the entire latitudinal range of the Northern Hemisphere, from a northern coastline in the Arctic zone to islands lying slightly south of the equator in Indonesia. Asian superlatives include the world's

- highest mountain (Mt. Everest, 8848m) and mountain range (Himalaya);
- largest highland plateau (Tibet);
- lowest terrestrial elevation (Dead Sea, -400m);
- largest (Caspian Sea, 143,200km^2) and deepest (Lake Baikal, 1620m) lakes; and
- coldest, most continental region except for Antarctica (northeastern Siberia), with mean monthly temperature ranging from 20°C to -60°C and extremes to -80°C.

as well as

- one of the world's three regions with essentially no rainfall (Tarim Basin); and
- two of the world's three stations with over 10 meters of average annual rainfall (windward slopes of easternmost India at Cherrapunji and Yakushima Island of Japan); and
- four of the world's seven rivers over 5000 km long (Yangtze, Ob'-Irtysh, Yenisey-Angara, and Huang-He).

Asia is also home to some of the oldest human cultures and to areas of very long, continuous human habitation, especially in the Middle East, India, and Southeast and East Asia.

Asia represents the largest part of Laurasia, the northern half of the super-continent Pangaea, which existed in the late Paleozoic and broke up during the Mesozoic (cf. Bridges 1990, Raven & Axelrod 1974). Eurasia began to separate from North America around 180 million (m) years ago, but contact was reestablished in the Cretaceous when Siberia approached Alaska, forming Beringia. About this time southwestern Asia also began to be influenced by northward moving Africa, a portion of Gondwana, the southern part of Pangaea. The present-day geologic and physiographic structure of Asia, however, is dominated by the Himalayan Mountains and Tibetan Plateau, which arose when India, another piece of former Gondwana, collided with Asia in the Eocene. In addition to the Himalaya itself, a mountain node was created at its western end, from which other major mountain ranges radiate in various directions. The most important of these is the Tien Shan-Altai system, which extends to the north-northeast into Mongolia, dividing interior, dry temperate Asia into:

1) a western part, called Middle Asia in Russian literature (essentially Turkestan and the Turanian Basin), influenced far inland by westerly winds from the Mediterranean; and

2) an eastern part, called Central Asia (essentially the Tibetan plateau and northwestern China, plus Mongolia) dominated by the Asian monsoon system.

Other radial ranges from the central node include the Hindu Kush mountains to the southwest, which separate Afghanistan from Pakistan; the Paropamisus and Kopet Dagh further west, which separate Afghanistan and Iran to the south from Turkestan to the north; and the Kunlun and Karakoram ranges which run east-west across the Tibetan Plateau. South of Tibet lies the Deccan Plateau of peninsular India, with its Eastern and higher Western Ghats ranges. Southeast of Tibet, the Yunnan-Guizhou Plateau (southwestern China) represents an upland transition to still mountainous Southeast Asia, with its Dawna and Arakan ranges (Burma) and Annamese cordillera.

In southwestern Asia, the Iranian Plateau (extending into Afghanistan), the Anatolian Plateau of central Turkey, and the Arabian Plateau (peninsula) have all been affected to some extent by the interaction between Africa and Asia. More linear mountain ranges in Asia include the Urals, the Hinggan-Ling and Changbai-Shan in northeastern China, and the Sikhote Alin, Kamchatkan, and other ranges of eastern Siberia. Major interior basins include the Turanian Basin east of the Caspian Sea, the West Siberian Lowland (the world's largest marshland), and the Tarim Basin of Central Asia. Other lowlands include the densely populated East China Plain and many river valleys of Asia: Ganga, Indus, Tigris-Euphrates, Brahmaputra, Irrawaddy, Yangtze, and Huang-He. Less populated lowlands extend along the Siberian coast (with the Taimyr peninsula) and the valleys of the Amur and north-flowing Lena, Yenisey-Angara, and Ob'-Irtysh rivers. The remaining structure of Asia is provided by the volcanic arcs forming the Kuril, Japanese, Okinawan, Philippine, and Indonesian archipelagos, along with continental islands such as Sri Lanka, Hainan, Taiwan, and the smaller Siberian Arctic islands and Andaman-Nicobar chain. All of these areas represent regions of localized environmental conditions and ecosystems, with more or less individual characteristics and diversity.

1) Climate

The single most important climatic feature of Asia is the monsoon system, which affects an area from Japan and northeastern China in the east, through China and Southeast Asia, to India and Sri Lanka in the south. The cooling of the vast mid-latitude land mass in the autumn and winter produces a very large, stable center of high atmospheric pressure over Mongolia and northern China, which feeds cold, dry air outward over the rest of East, Southeast, and South Asia throughout the winter. As a result, and aided perhaps by the many east-west mountain ranges, mean winter temperatures are generally low but extremes are not far below the means (e.g. Box 1995). In summer, continental warming causes rising air, which draws wet air masses in off the adjacent Pacific and Indian Oceans. This greatly accentuates the rainier season which, due to global atmospheric circulation, would occur in summer over most of this area anyway. The "summer monsoon" arrives as two almost stationary rain fronts which, over the course of about one month, penetrate from Kerala across the rest of India and from Japan across Korea into eastern China. Although the monsoon quickly brings warm rains to South Asia, it brings a cooler, mistier rainy season as it crosses Japan into Korea and China. The cold, dry winter is much more reliable than the summer rains. Heavy winter snow can delay the warming of the land mass to such an extent that the summer monsoon "fails" in places such as India, with disastrous affects on crops.

The Philippines and East Indies are less affected by the monsoon and more by the seasonal shift in global circulation. Near the equator, warm perhumid conditions continue throughout most of the year, with only a short dry season if any at all. The length and degree of the dry season increase away from the equator, reaching several months in the northern Philippines but also in some eastern parts of Indonesia. Southwestern Asia is not affected by the monsoon, although the pervasive effect of subtropical high pressure does provide a dominant influence on climate as far east as the Thar desert in Pakistan and western India.

Northern Asia (Siberia) is dominated by its high latitude and large land area, resulting in ultra-continental climates with short summers and long severe winter rivaling the northern polar region in degree of cold. For further geographic treatment of the climatic situation of Asia, especially of eastern and southern Asia, see Suslov (1961), Fukui (1977), Wolfe (1979), Chang (1983), China Natural Geography (1984), Zhao (1986), Kira (1991), Box (1995).

2) Vegetation

Vegetation patterns largely follow climate. A world zonation of climates and natural biomes, with associated variants of the main zonal vegetation type and vertical zonation in mountains, is given in the following table, based on the climate types of Heinrich Walter (cf Walter 1977), as expanded by Box (cf Box 1995). All of these climate zones occur in Asia except Vm (Marine West-Coast), which is in Europe. This zonation serves as the initial basis for recognizing landscape regions in Asia.

Biome	Climate	Associated Ecosystems	Montane Zonation
Tropical Rainforest	I	Semi-EG forest, drier EG forests and woodlands, scrub, savannas	Paramo Cloud forest Mont. rainforest
Tropical Deciduous Forest and Woodlands	II	Drier raingreen/EG woodlands, thorn-scrub, campos, savannas	Moist puna EG mont. forest Semi-EG forest
- Tropical Savanna	II-III	Thorn-scrub	
Warm Desert/ Semi-Desert	III	Xeric shrub-steppe, oases, wadis, sand desert, rock desert, playas	Dry puna grassland Montane scrub
Mediterranean Forests, Woodlands, Shrublands	IV	Degraded scrub, shrub-steppe, sclerophyll savanna-woodland	Dry cushion-scrub Mont. conif. forest
Temperate Rainforest (evergreen broad-leaved)	Vm	Summergreen forest, cool-maritime heaths	Wet alpine tundra Subalpine conifers
Evergreen "Laurel" (broad-leaved) Forest	Ve	Pine woods, summergreen forest, subtropical rainforest	Alpine tundra Subalp. conifers Mont. mixed forest
Temperate Deciduous (summergreen) Forest	VI	Pine woods, grasslands, temperate heaths and wetlands	Alpine tundra Subalpine conifers Mont. mixed forest
Temperate Grassland (prairie, steppe)	VII	Grove belts, riparian forests, degraded steppes; wetlands	Dry alpine tundra Subalpine conifers Mont.dry conifers
- Temperate Desert/ Semi-Desert	VIIa	Riparian woods, salt flats, sand and rock deserts	

Boreal Forest (evergreen coniferous)	VIII	Larch forest, open conifer woods, forest-tundra, bogs	Alpine tundra
Polar Tundra	IX	Riparian/other wetlands, moss-lichen cold-desert	- - - - -

(EG = evergreen; mont. = montane)

Some major world and regional vegetation descriptions that pertain to Asia, at least in part, include:

World:	Schmithüsen 1968, Eyre 1968; Walter 1968, 1973, 1985; Archibold 1995
Tropics:	Schnell 1970-77; Whitmore 1984
Mountains:	Chen et al. 1986, Numata 1983; Troll 1959, 1972a, 1972b; Ohsawa 1993; Hamilton et al. 1995; Zobel & Singh 1997
Eurasia (northern):	Alekhin 1951, Walter 1974
Asia (dry):	Popov 1940, Yunatov 1950, Korovin 1961-62, Petrov 1966-67, Davis et al. 1971, Freitag 1971, Zohary 1974, Breckle 1983, Walter & Box 1983
Asia (tropical):	Ogawa et al. 1961; Champion et al. 1965, 1968; Williams 1965
Asia (eastern):	Wang 1961, Numata et al. 1972, Numata 1974; Hou 1979, 1983; Wu 1980, 1995; Miyawaki 1980-89; Song 1983; Box et al. 1995; Kolbek et al. 2003

3) Human Impact

It is difficult to show human impact on a broad-scale vegetation map, especially if the map is based on physiognomy. Nevertheless, most of Asia (largely excluding Russia) is covered with substitute vegetation resulting from human activities. This is especially true in China, Japan, and Southeast Asia. On the map, these converted landscapes are shown as cultivated area (cropland and paddy field), needle-leaved evergreen forest (tree plantations) and broad-leaved deciduous forest within the climatic broad-leaved evergreen forest region. Even most of the deciduous forest in the temperate zone (Manchuria, Russian Far East, Korea, and northern Japan) is also secondary forest, as determined from field surveys. Natural forests remain only in protected areas such as national parks. The forests surrounding cropland are mostly secondary forests to be used for firewood or charcoal production. Especially in China and Southeast Asia, areas of high population density were converted to cropland and deciduous-forest mosaics. In the boreal zone, broad-leaved deciduous forests result from wildfires.

In Southeast Asia, most lowland forests (up to 800m) are so-called dry dipterocarp forests, a type of tropical deciduous forest. Dry dipterocarp forests occur naturally on areas of shallow soil or on steep slopes of hills or mountains. The area of such forests is expanded, however, by fire and frequent cutting. Even many scientists in the tropics and other countries believe that these are the natural vegetation, even though they are secondary forests, because already the soil has eroded and became shallower, and the local climate has become drier. There is a good example at Sakaerat in Thailand. A Thai-Japanese cooperative facility there has kept a fire-free area, in which the typical natural dry evergreen forest remains. The adjacent area is dry dipterocarp forest resulting from fire (see p. 000).

From the satellite data, it is difficult to classify needle-leaved evergreen forests as tree plantation or natural boreal forest. In temperate to subtropical zones, most needle-leaved evergreen forests are tree plantations, involving *Pinus, Cryptomerya, Chamaecyparis, Cupressus,* etc.

Scrub occurs mainly in temperate China and in southern Manchuria and Korea. East-central China is covered by *Sophora, Populus*, and other scrub for sewings seed or by planted deciduous trees. Even secondary deciduous forests in this region are included in scrub.

Natural grassland occurs in areas with dry climate. Most grassland is pasture or mowed areas, especially in central to Far Eastern Russia. Even semi-desert are also mowed in Tibet, Qinghai, Inner-Mongolia, etc.

Human impacts in Asia can be classified into five types: cultivation, cutting, fire, grazing and plantation. We can see how much nature we do not have in Asia by looking at the vegetation map.

References

Alekhin, V. V. 1951. (*Vegetation of the USSR in its Fundamental Zonation*). 2nd ed. Moscow. 512 pp + map (in Russian).

Archibold, O. W. 1995. *Ecology of World Vegetation*. Chapman and Hall, London. 510 pp.

Box, E. O. 1995. Global and local climatic relations of the forests of East and Southeast Asia. In: *Vegetation Science in Forestry* (E. O. Box et al., eds.), Handbook Vegetation Sci., vol. 12/1, pp. 23-55. Dordrecht.

Box, E. O., and K. Fujiwara 2001. Ecosystems of Asia. In: *Encyclopedia of Biodiversity* (S. Levin et al., eds.), vol. 1, pp. 261-291. Academic Press, San Diego.

Box, E. O. (ed.), with R. K. Peet, T. Masuzawa, I. Yamada, K. Fujiwara and P. F. Maycock (co-eds.) 1995. *Vegetation Science in Forestry: Global Perspective based on Forest Ecosystems of East and Southeast Asia*. Handbook of Vegetation Science, vol. 12/1. Dordrecht: Kluwer. 663 pp.

Breckle, S. W. 1983. Temperate Deserts and Semi-Deserts of Afghanistan and Iran. In: *Temperate Deserts and Semi-Deserts* (N. West, ed.), pp. 271-319. Elsevier, Amsterdam.

Bridges, E. M. 1990. *World Geomorphology*. Cambridge University Press. 260pp.

Champion, H. G., S. K. Seth, and G. M. Khattak 1965. *Forest Types of Pakistan*. Forest Research Institute, Sukkur.

Champion, H. G., and S. K. Seth 1968. *A Revised Survey of the Forest Types of India*. Government Printer, Delhi.

Chang D. H. S. 1983. The Tibetan Plateau in relation to the vegetation of China. *Ann. Missouri Bot. Gard.*, 70:564-570.

Chen L.-Zhi, Chang Hs.-Sh., and Committee 1986. *Proceedings of the International Symposium on Mountain Vegetation*. Beijing: Botanical Society of China. 297 pp.

China Natural Geography Editorial Committee (eds.) 1984. (*China Natural Geography: Climate.*) Academia Sinica. Science Press, Beijing. 161 pp. (in Chinese).

Davis, P. H., P. C. Harper, and I. C. Hedge 1971. *Plant Life of South-West Asia*. Botanical Society of Edinburgh. 335 pp.

Eyre, S. R. 1968. *Vegetation and Soils, a World Picture*. 2nd ed. Chicago.

Freitag, H. 1971. Die natürliche Vegetation Afghanistans. *Vegetatio*, 22:285-344.

Fukui, E. (ed.) 1977. *The Climate of Japan*. Kodansha, Tokyo. 317 pp.

Hamilton, L. S., et al. (eds.) 1995. *Tropical Montane Cloud Forests*. Ecological Studies, vol. 110. Springer-Verlag, New York.

Hou X.-Yu (ed./author-in-chief) 1979. (Vegetation Map of China.) Institute of Botany, Academia Sinica. Map Press, Beijing. Map (1:4,000,000, in Chinese) + separate legend manual (Chinese and English versions, 12 pp).

Hou X.-Yu 1983. Vegetation of China with reference to its geographical distribution. *Ann. Missouri Bot. Garden*, 70:509-548.

Kira, T. 1991. Forest ecosystems of East and Southeast Asia in a global perspective. *Ecol. Res.*

(Japan), 6:185-200. Reprinted in: *Vegetation Science in Forestry* (E. O. Box et al., eds.), pp. 1-21.

Kolbek, J., M. Srutek, and E. O. Box (eds.) 2003. *Forest Vegetation of Northeast Asia.* Kluwer, Dordrecht. 462pp.

Korovin, E. P. 1961-62. (*The Vegetation of Middle Asia and Southern Kazakhstan*). 2nd ed. Tashkent. 452 pp. + 577 pp. (2 vols., in Russian).

Miyawaki, A. (ed.), 1980-1989. *Nihon Shokusei Shi* (Vegetation of Japan). 10 vols., each about 400-700 pp, with separate volumes of vegetation tables and of color maps (in Japanese, with German or English summary). Shibundo, Tokyo.

Numata, M. (ed.) 1974. *The Flora and Vegetation of Japan.* Kodansha (Tokyo) and Elsevier (Amsterdam). 294 pp.

Numata, M. (ed.) 1983. *Biota and Ecology of Eastern Nepal.* Himalayan Committee of Chiba University (Japan). 485 pp.

Numata, M., A. Miyawaki, and D. Itow 1972. Natural and semi-natural vegetation in Japan. *Blumea*, 20:435-481 (with 26 photos, veg. maps).

Ogawa, H. K. Yoda, and T. Kira 1961. A preliminary survey on the vegetation of Thailand. *Nature and Life in SE Asia*, 1:21-157.

Ohsawa, M. 1993. Latitudinal pattern of mountain vegetation zonation in southern and eastern Asia. *J. Vegetation Sci.*, 4:13-18.

Petrov, M. P. 1966-67. (*The Deserts of Central Asia*). 2 vols. Moskva-Leningrad. 274 pp. + 286 pp. (in Russian).

Popov, M. G. 1940. (*The Plant Cover of Kazakhstan*). Moskva. 216 pp. (in Russian).

Raven, P. H., and D. I. Axelrod 1974. Angiosperm biogeography and past continental movements. *Annals Missouri Bot. Garden*, 61:539-673.

Schmithüsen, J. 1968. *Vegetationsgeographie*. 3rd edition. Walter de Gruyter, Berlin. 463 pp.

Schnell, R. 1970-77. *Introduction à la Phytogéographie des Pays Tropicaux.* 4 vols. Gauthier-Villars, Paris.

Song Y.-Ch. 1983. Die räumliche Ordnung der Vegetation Chinas. *Tuexenia*, 3:131-157.

Suslov, S. P. 1961. *Physical Geography of Asiatic Russia.* Translated from Russian by N. D. Gershevsky (J. E. Williams, ed.). W. H. Freeman, San Francisco. 594 pp.

Troll, C. 1959. Die tropischen Gebirge. *Bonner Geogr. Abhandl.*, 25.

Troll, C. 1972a. The three-dimensional zonation of the Himalayan systems. In: *Geoecology of the High-mountain Regions of Eurasia* (C. Troll, ed.), pp, 264-275. Steiner-Verlag, Wiesbaden.

Troll, C. (ed.) 1972b. *Geoecology of the High-Mountain Regions of Eurasia.* Erdwissenschaftl. Forschung, vol. 4. Franz-Steiner-Verlag, Wiesbaden.

Walter, H. 1968. *Die Vegetation der Erde in öko-physiologischer Betrachtung.* Vol. II: Die gemäßigten und arktischen Zonen. Jena: VEB Gustav-Fischer-Verlag. 1002 pp.

Walter, H. 1973. *Die Vegetation der Erde in öko-physiologischer Betrachtung.* Vol. I: Die tropischen und subtropischen Zonen. Stuttgart: VEB Gustav-Fischer-Verlag. ??? pp.

Walter, H. 1974. *Die Vegetation Osteuropas, Nord- und Zentralasiens*. "Vegetation der einzelnen Großräume" series, vol. VII. Gustav-Fischer-Verlag, Stuttgart. 452 pp.

Walter, H. 1977. *Vegetationszonen und Klima*. 3rd ed. Stuttgart: Eugen-Ulmer-Verlag. 309 pp.

Walter, H. 1985. *Vegetation of the Earth and Ecological Systems of the Geobiosphere*. 3rd ed. Spinger-Verlag, New York. 318 pp.

Walter, H., and E. O. Box 1983. Chapters 2-9 (deserts of Eurasia) in: *Temperate Deserts and Semi-Deserts* (N. E. West, editor). Ecosystems of the World, vol. 5. Elsevier, Amsterdam.

Wang Chi-Wu 1961. *The Forests of China, with a Survey of Grassland and Desesrt Vegetation.* Maria Moors Cabot Foundation Publ. no. 5. Harvard University, Cambridge (Mass.). 313 pp.

Whitmore, T. C. 1984. *Tropical Rainforests of the Far East*. 2nd edition. Clarendon Press, Oxford. 362 pp (1st edition 1975, 282 pp).

Williams, L. 1965. *Vegetation of Southeast Asia: Studies of Forest Types 1963-1965*. U.S. Dept. Agriculture, Washington. 302 pp.

Wolfe, J. A. 1979. Temperature parameters of humid to mesic forests of eastern Asia and relation to forests of other regions of the Northern Hemisphere and Australasia. Washington: U.S. Geological Survey, Professional Paper No. 1106. 37 pp.

Wu Zh.-Y. and committee (eds.) 1980. *Zhongguo Zhibei* (Vegetation of China). Science Press, Beijing. 1375 pp + 339 B/W photos (in Chinese, Latin-Chinese species lists; no index).

Yunatov, A. A. 1950. *The Main Features of the Plant Cover of the Mongolian People's Republic*. Publ. Mongol.

Zhao S.-Q. 1986. *Physical Geography of China*. Science Press (Beijing) and John Wiley & Sons (New York). 209 pp + color photographs.

Zobel, D. B., and S. P. Singh 1997. Himalayan forests and ecological generalizations. *BioScience*, 47:735-745.

Zohary, M. 1974. *Geobotanical Foundations of the Middle East*. "Geobotanica Selecta" series, vol. III. Gustav-Fischer-Verlag, Stuttgart. 340 pp.

II. Study Area, Methodology and Data

Elgene O. Box (*Department of Geography, University of Georgia, Athens, Georgia, USA*)

Kazue Fujiwara (*Graduate School of Environment and Information Sciences, Yokohama National University, Yokohama, Japan*)

Asia is too large to survey completely in four years. Also, it is simply too dangerous to visit some areas. So this project focuses on most of traditional Monsoon Asia (from Japan to Myanmar), adjacent interior Asia, and northern Eurasia, i.e. all of Russia (since the old maps also include the European parts). The rest of Asia is excluded because it was simply too much for this project. A first next step may be to extend the classification and maps to the Indian subcontinent and into dry Middle Asia.

The project involved two main methodologies. The first is extensive field survey of natural and related vegetation in representative areas over as large a part of Asia as possible. The second methodology is computer mapping, based on satellite data and first-hand understanding the vegetation, its environmental relationships, and its dynamics.

1. Field Survey

Some recent large-area field surveys of vegetation are listed in the following table.

Project	Dates	Product	Publication
Vegetation Survey of Western Australia	1970s	maps: 1:1,000,000 series + 1:250,000 series	Beard 1974-81
Vegetation of China	1970s	map + manual book (2 editions)	Hou et al. 1979; Wu 1980, 1995
Vegetation of Japan (*Nippon Shokusei-Shi*)	1980s	10 vols + maps + phytosoc. tables	Miyawaki 1980-89
Vegetation syntheses in N & central Europe, including the Alps	1980s-90s (1950-70s)	books of community and vegetation types, mainly phytosociological	Ellenberg 1963, Pott 1995, Dierßen 1996
European Vegetation Survey	1980s-90s	maps: sheets & composite, handbook, prodromus	Udo Bohn & team, Rodwell et al. 02
Eastern North American Vegetation Survey	1988-90	book	Miyawaki et al. (eds.) 1995
South African Vegetation Survey	1990s	maps and handbook	Bredenkamp et al.
Boreal and western temperate North America	1990s	book of phytosociological community types, + map	Rivas-Martinez et al. 1999

Such surveys can serve as a useful guide, and some members of this project's team have experience with two of these earlier surveys:

1) the "Vegetation of Japan" project (Fujiwara, Nakamura, Ohno), which documented all vegetation types of Japan in great detail (Miyawaki, ed., 1980-89); and
2) the "Eastern North American Vegetation Survey" (Fujiwara, Box), which described the vegetation of North America east of the Appalachian Mountains (including eastern Canada and the southeastern US west to New Orleans) (Miyawaki et al, eds., 1995).

In a large-area field survey, the main steps are as follow:

- Identification of basic landscape types, over the entire large study area;

- Field study, in representative areas, by full-floristic vegetation sampling (Braun-Blanquet relevés);
- Data synthesis for understanding of vegetation composition, structure, and dynamics; and

- Understanding the spatial extent, texture, and scale of the various vegetation types and areas – which vegetation types can be mapped and which not, at the scale of the maps to be produced?

Basic regionalization of vegetation and landscapes is based on the zonal framework shown above in the section on "Asia the Region". This also led to an initial draft of the map legend, in 2004, before extensive fieldwork began. This legend draft served as the geographic framework guiding the fieldwork and other efforts to find training sites for interpreting the satellite data.

The field inventory itself was performed according to the Braun-Blanquet (cf 1964) methodology, most closely following the procedures described by Fujiwara (1987). Other descriptions of the basic methodology are given by Mueller-Dombois and Ellenberg (1974), Kent and Coker (1992), and Westhoff and van der Maarel (1973).

Fieldwork was performed mainly in the summer but also in autumn and over Christmas breaks, as time permitted, during the years 2004-2007. The following areas were studied during the project (by multiple members of project team, unless otherwise indicated):

Russia:
southern boreal forests of St. Petersburg area, European Russia (July 2004)
nemoral oak forests around Kazan', on the Volga River (August 2004)
meadow-steppe transition on Mongolian border south of Chita (August 2004)
forest in Primorye (August-September 2005)
boreal larch forests and steppes of ultra-continental central Yakutia (July-August 2006)
forests and coastal vegetation of southern Sakhalin (August 2006)
sub-polar woodlands and Arctic tundra of northeast Siberia (June-July 2007)
montane forests, steppe and semi-desert, Sayany Mtns., SW Siberia (July-August 2007)
forest vegetation along Amur River (September 2007)

China:
warm-temperate and subtropical forests of Fujian (December 2004)
desert vegetation and montane forests of Dzungaria (Xinjiang, June 2005)
semi-desert vegetation of Kashgaria and the Tarim Basin (Xinjiang, July 2005)
evergreen and semi-evergreen broad-leaved forests, W Hunan-Chongqing (Dec. 2005)
heavily man-influenced landscapes at Beijing, Linxi, and Xian (June 2006)
montane deciduous and conifer forests of dry-climate Gansu (July 2006)
temperate deciduous forest in Manchuria (August 2006)
alpine tundra in Tibet (September 2006)

Korea
forest vegetation along Nakutong River (August 2004)
forest vegetation in southern Korea (September 2005)

SE Asia:
mangroves and substitute vegetation in peninsular Thailand (February 2004)
mangrove vegetation in southern Thailand (September 2005)
tropical forests of northern Myanmar (December 2006)
tropical forests of central to southern Laos (December 2007)

Information was also available from earlier work by members of the project team. The following areas had been studied before the project began and were also familiar; in some cases field data were available, sometimes extensive data:

ex-USSR:
By Russian colleagues: much of Siberia and the Russian Far East (over many years, from 1980s onward)
Kuril and Kommander Islands (September 2003: Krestov)

By non-Russian team members:
- forests and coastal areas of southern Primorye (August 2003)

- boreal forests and volcanic areas in southern Kamchatka (August 2003)
- southern boreal forests and forest-steppe, Lake Baikal (Aug. 1994: Fujiwara, Box)
- deciduous forests and sub-Mediterranean vegetation of the Crimea (June 1999: Box)
- forests, Tatar steppe, xeric woodlands, and mountain vegetation of Georgia (Caucasus, June 1999: Fujiwara, Box
- vegetation of Russian Far East (Sakhalin, Kamchatka, Primorye, Khabarovsk: Nakamura, Krestov, 2000 onward)

China: By Chinese colleagues: much of China, especially eastern (from 1960s onward)

By non-Chinese team members, with Chinese colleagues:
- transitional evergreen and deciduous forests of eastern China (Tiantong, November 1985: Fujiwara, Box, 1995-1998: Nakamura)
- tropical montane forests and mangroves of Hainan (September 1986: Fujiwara, Box)
- evergreen broad-leaved and montane forests of Sichuan and Yunnan and of Guangdong (autumn 1986 and 1988: Fujiwara, Box)
- vegetation zonation of the Changbai-Shan mountains (September 1992: Box)
-vegetation survey in Shanghai and adjacency (1995-2000: Nakamura)
- deciduous forests, montane larch forests, and Mongolian steppe (with pine-forest outliers) in Manchuria (June-July 2000: Box, Fujiwara)
-deciduous forests in Manchuria (2000-2006: Fujiwara, You)
- Mongolian steppe and dry montane forest, Inner Mongolia (July 2002: Fujiwara, Box)
-dry deciduous forests (Inner Mongolia, Gansu, Shanxi, Henan, Hebei, 2000, onward)
-temperate deciduous forests in Beijing and adjacency (1997-1998: Fujiwara)
-warm-temperate forests in eastern China (Jiangsu, Shandong, Anhui, 1999-2000: Fujiwara, You)
- warm-temperate forests of east China (Guizhou & Zhejiang, December 2002)

Japan: All parts and vegetation types, including the Okinawan Islands and Iwo-Jima and the Ogasawara Islands in the Pacific Ocean (from 1970s onward)

Korea: vegetation zonation of Mt. Seolag (Sorak), warm-temperate evergreen and montane forests of Cheju-dô island (autumn, late 1980s: Fujiwara, Box)
forest vegetation in South Korea (Ohno, Mochida, and since 2000)

Taiwan: evergreen broad-leaved and montane forests, mangroves, other coastal vegetation (November 1987: Fujiwara, Box)
forest vegetation in Taiwan (2006: Nakamura)

Himalaya: mountain forest zonation (Nepal 2002, Bhutan 2004, 2006: Fujiwara)

Thailand: forests of northern highlands (1979-1981: Nakamura, Fujiwara)
mangroves (1979-1981: Fujiwara, Nakamura, and since)

Outside study area but instructive:

Malaysia: tropical rainforest of Sarawak, vegetation zonation of Mt. Kinabalu (summer 1990: Box, 1990-2004: Fujiwara)

Sri Lanka: vegetation of highlands, tropical rainforest, and coastal vegetation (August 1982: Box; February 2002: Fujiwara)

Philippines: vegetation survey in southern Luzon (1993, 2008: Fujiwara)

Japan: project members survey during project years as well as before

Fieldwork during the four-year project and before, by team members and other colleagues, resulted into this report.

2. Symposia and Workshops

1. Aug. 1-5, 2004: Workshop for Integrated vegetation mapping in Asia, at Komarov Botanical Institute, Saint Petersburg, Russia.
2. Jan. 5, 2005: Workshop in Chiba, Japan.
3. Mar. 25-28, 2006: Symposium of Integrated vegetation mapping in Asia, Niigata, 3rd EAFES.
4. Jan. 4, 2006: Workshop in Chiba, Japan.
5. May 22-27, 2007: Symposium of Vegetation in Asia -for sustainable management and restoration, Eco-Summit, Beijing, China.
6. Oct. 15, 2007: Workshop in Chiba, Japan.
7. Oct. 21-22, 2007: Workshop in Shanghai, China.
8. Dec. 15, 2007: Workshop in Chiba, Japan.

References

Beard, J. S. 1974-1981. Vegetation Survey of Western Australia. Vegmap Publications and University of Western Australia Press. Perth.

Braun-Blanquet, J. 1964. *Pflanzensoziologie*. 3rd edition. Springer-Verlag.

Dierßen, K. 1996. *Vegetation Nordeuropas*. Verlag Eugen Ulmer, Stuttgart. 838pp.

Ellenberg, H. 1963. *Vegetation Mitteleuropas mit den Alpen*. Verlag Eugen Ulmer, Stuttgart. (5th edition 1996). 1095pp.

Fujiwara, K. 1987. Aims and methods of phytosociology or "vegetation science." In: *Papers on Plant Ecology and Taxonomy to the Memory of Dr. Satoshi Nakanishi* (Y. Takeda, ed.), pp. 607-628. Kôbe Geobotanical Society.

Hou X.-Yu (ed.) and Institute of Botany 1979. (Vegetation Map of China). Academia Sinica and Map Publisher of People's Rep. of China. (In Chinese)

Kent, M., and P. Coker 1992. *Vegetation Description and Analysis*. John Wiley & Sons, Chichester. 363pp.

Miyawaki, A. (ed.), 1980-1989. *Nippon Shokusei Shi* (Vegetation of Japan). 10 vols., each about 400-700 pp, with separate volumes of vegetation tables and of color maps (in Japanese, with German or English summary). Shibundo, Tokyo.

Miyawaki, A., K. Iwatsuki, and M. M. Grandtner (eds.) 1995. *Vegetation in Eastern North America.* University of Tokyo Press. 515pp.

Mueller-Dombois, D., and H. Ellenberg 1974. *Aims and Methods of Vegetation Ecology*. New York: Wiley. 547 pp.

Pott, R. 1995. *Die Pflanzengesellschaften Deutschlands*. 2nd edition. Verlag Eugen Ulmer, Stuttgart.

Rivas-Martinez, S., D. Sanchez-Mata, and M. Costa 1999. North American boreal and western temperate Forest vegetation. *Itinera Geobotanica*, 12:5-316.

Rodwell, J. S., J. H. J. Schaminée, L. Mucina, S. Pignatti, J. Dring, and D. Moss 2002. The Diversity of European Vegetation. Report EC-LNV 2002/054, Wageningen.

Westhoff, V., and E. van der Maarel 1978. The Braun-Blanquet Approach. In: *Classification of Plant Communities* (R. H. Whittaker, ed.), pp. 289-374. Dr. W. Junk bv, The Hague.

Wu Zh.-Y. and committee (eds.) 1980. *Zhongguo Zhibei* (Vegetation of China). Science Press, Beijing. 1375 pp + 339 B/W photos (in Chinese, Latin-Chinese species lists; no index).

2. Remote sensing analysis

Ryutaro Tateishi (*Center for Environmental Remote Sensing, Chiba University, Chiba, Japan*)

(1) Satellite data used

The satellite data used for the vegetation mapping in this project were the Moderate Resolution Imaging Spectroradiometer (MODIS) data observed in 2003. The MODIS sensor, installed on the Terra satellite, was launched into space by NASA in December 1999.

Table 3.1 shows characteristics of the Terra satellite. The MODIS sensor has 36 bands. Since bands 1-7 are suitable for land applications, these bands were used for this project. Table 3.2 shows the bandwidth of bands 1-7.

Table 3.1 Characteristics of the Terra satellite

Orbit:	705 km, 10:30 a.m. descending node, sun-synchronous, near-polar, circular
Swath Dimensions:	2330 km (cross track) by 10 km (along track at nadir)
Size:	1.0 x 1.6 x 1.0 m
Weight:	228.7 kg
Quantization:	12 bits
Spatial Resolution:	250 m (bands 1-2) 500 m (bands 3-7) 1000 m (bands 8-36)

Table 3.2 Bandwidth of the MODIS bands 1-7.

Primary Use	Band	Bandwidth (nm)
Land/Cloud/Aerosols Boundaries	1	620 - 670
	2	841 - 876
Land/Cloud/Aerosols Properties	3	459 - 479
	4	545 - 565
	5	1230 - 1250
	6	1628 - 1652
	7	2105 - 2155

The source of MODIS data is the "MODIS/TERRA Nadir BRDF- Adjusted Reflectance 16-DAY L3 Global 1 KM SIN Grid Product (MOD43B4 NBAR)" from the U.S. Geological Survey. The source MODIS data were processed further at the Center for Environmental Remote Sensing (CEReS), Chiba University. This processing included mosaicking, reprojection, and clearing contamination by cloud pixels. Table 3.3 shows characteristics of the processed MODIS data at CEReS.

Table 3.3 Characteristics of processed MODIS data

Characteristics of processed MODIS data (CEReS, Chiba University)

Spectral Bands: bands 1-7
Resolution: 32.3748 seconds (approximately 1 kilometer).
Temporal Composite: 16-day (see Table 3.4)
Year: 2003.
Data Format: Geo-Tiff.
Data Type: 16-bit Unsigned.
Digital Data: 0 - 32767 (Ocean: 32767).
Projection: Geographic map projection (Lat/Long).
Reference Datum: WGS84.
Geographic region: 5N-80N latitude 40E-167W longitude
More accurately
4° 59′21″79 N - 80° 00′0″00N latitude
39° 59′6″63E - 167° 00′28″13W longitude

Table 3.4 Periods of MODIS composite

Period No., Year and day No.	Start Date	End Date
1- 2003 – 01	2003-01-01	2003-01-16
2- 2003 – 17	2003-01-17	2003-01-31
3- 2003 – 33	2003-02-02	2003-02-17
4- 2003 – 49	2003-02-18	2003-03-05
5- 2003 – 65	2003-03-06	2003-03-21
6- 2003 – 81	2003-03-22	2003-04-06
7- 2003 – 97	2003-04-07	2003-04-22
8- 2003 – 113	2003-04-23	2003-05-08
9- 2003 – 129	2003-05-09	2003-05-24
10- 2003 – 145	2003-05-25	2003-06-09
11- 2003 – 161	2003-06-10	2003-06-25
12- 2003 – 177	2003-06-26	2003-07-11
13- 2003 – 193	2003-07-12	2003-07-27
14- 2003 – 209	2003-07-28	2003-08-12
15- 2003 – 225	2003-08-13	2003-08-28
16- 2003 – 241	2003-08-29	2003-09-13
17- 2003 – 257	2003-09-14	2003-09-29
18- 2003 – 273	2003-09-30	2003-10-15
19- 2003 – 289	2003-10-16	2003-10-31
20- 2003 – 305	2003-11-01	2003-11-16
21- 2003 – 321	2003-11-17	2003-12-02
22- 2003 – 337	2003-12-03	2003-12-18
23- 2003 – 353	2003-12-19	2003-12-31

(2) Legend for vegetation for classification and training data

The vegetation classification system (legend) to be used was prepared originally by Elgene Box (cf Box 1995, see section on Legend) and modified at team meetings in 2005, 2006, and 2007. Based on this legend, a code for vegetation classes, called the “Box code,” was defined, as shown in Table 3.5. The right-hand column of the Table shows the number of training polygons collected. For example, item 2-1 has 4 training polygons, and 34 training polygons were collected for item 2 independently. The second level in the Box code was not identified for these 34 polygons. The total number of training polygons was 745. Broad-Leaved Evergreen Forests (Box code 1), Forest-Steppe Ecotone (Box code 5), Open Water (Box code 15), and Urban Areas (Box code 16) have no training data. Table 3.6 shows a list of each shape file of training data. Two additional classes, for “Mixed forest” and “Cropland/other vegetation mosaic”, were included. These classes are not included in the Box system of vegetation classes.

Training data were collected mainly by the vegetation scientists, using Landsat images, based on their experience of expedition and their knowledge. Additional training data were colleted by Ryutaro Tateishi with his students and by Hiroshi Sato, in order to compensate insufficient parts, using Landsat, Google Earth and existing maps. Fig.3.1 shows the distribution of all training data collected.

Table 3.5 Box vegetation class code and training polygons

Vegetation Name	Box code 1st level	Box code2nd level	Number of training polygons
1. Broad-Leaved Evergreen Forests	1		
1) Tropical Rainforest and seasonal Evergreen Forest		1-1	
2) Tropical Dry Evergreen Forest		1-2	
3) Evergreen Broad-Leaved Forest (subtropical/warm-temperature)		1-3	
2. Broad-Leaved Deciduous Forests and Woodlands	2		34
1) *Betula/Populus* (boreal) Forests		2-1	4
2) *Populus* Forests (non-boreal)		2-2	
3) Temperate BL-Deciduous (summergreen) Forest		2-3	3
4) Secondary BL-Deciduous Forest in evergreen zone		2-4	
5) Temperate Mixed Forest (BL-Deciduous + Coniferous, e.g. *Pinus koreana*)		2-5	5
6) Subboreal/Montane Mixed Forest (BL-Deciduous+ Coniferous, e.g. *Pinus* + *Betula*)		2-6	
7) Deciduous Tree Plantation (China)		2-7	
8) Tropical Deciduous Forests and Woodlands (e.g. Dry-Dipterocarp, *Macaranga*)		2-8	
3. Needle-Leaved Evergreen Forest (and Woodland)	3		25
1) Boreal and subalpine Forests (*Picea*, *Abies*, etc.)		3-1	1
2) Open boreal Taiga (*Picea*, *Pinus*, inc. grassy open conifer stands)		3-2	
3) Secondary Pine Forests (temperate, warm-temperate/subtropical)		3-3	17
4) Conifer Plantations (e.g. *Cryptomeria, Chamaecyparis, Pinus*)		3-4	12
4. Needle-Leaved Deciduous Forests (and Woodland)	4		20
1) Boreal Larch Forests (*Larix*, including *Larix + Picea*)		4-1	
2) Open Larch Taiga (including *Larix* + *Pinus pumila* undestorey)		4-2	3
3) Larch Plantation (deciduous)		4-3	
5. Forest-Steppe Ecotone (mainly *Populus tremula* groves + grassland)	5		
6. Scrub vegetation	6		108
1) Scrub in Evergreen-Broadleaf region (substitute vegetation)		6-1	26
2) Krummholz (evergreen *Pinus pumila*)		6-2	2

3) Summergreen scrub (subarctic and subalpine)		6-3	
4) Summergreen scrub (temperate secondary scrub)		6-4	
7. Bamboo and Sasa Stands	7		
1) Bamboo Forest		7-1	12
2) Sasa Thickets		7-2	
8. Grassland and Meadows	8		139
1) Steppe (typical temperate grassland)		8-1	1
2) Montane Grassland in warmer areas (e.g. *Imperata*)		8-2	
3) Meadows and Pastures		8-3	
9. Semi-Desert and Desert Vegetation (including alpine)	9		20
1) Semi-Desert Grassland		9-1	15
10. Tundra Vegetation	10		
1) Dwarf-Shrub Tundra (e.g. *Salix, Betula*, evergreen Ericaceae)		10-1	9
2) Graminoid Tundra (sedges)		10-2	
3) Alpine Tundra (generally mixed)		10-3	6
4) Alpine Semi-Desert (e.g. *Dicentra, Polygonum, Papaver, Minuartia, Saxafraga*)		10-4	1
11. Wetlands and Riverside Vegetation	11		11
1) Mires (fens and bogs)		11-1	
2) Wet Meadows		11-2	
3) Riparian Forests		11-3	
4) Mangrove forests		11-4	
12. Paddy Fields	12	12	110
13. Cropland	13	13	131
14. Bare Land	14		30
1) Arid desert		14-1	
2) Polar and alpine cold desert		14-2	
3) Ice desert		14-3	
15. Open Water	15	15	
16. Urban Areas	16	16	
total			745

Table 3.6 List of training shape files

shape fileNo.	Class No.	Box Code	Tentative name	shape file name	Collected by	Number of polygons (for each shape file)	Number of polygons (for each class)
1	72	2-1	Tree cover broad-leaved deciduous closed	A64	T	4	46
2	19	2	Broad-leaved deciduous forest	EU-N-Forest16	T	7	
3	20	2	Broad-leaved deciduous forest	EU-N-Forest17	T	1	
4	21	2	Broad-leaved deciduous forest	EU-N-Forest18	T	13	
5	22	2	Broad-leaved deciduous forest	EU-N-Forest19	T	2	
6	25	2	Broad-leaved deciduous forest	EU-N-Forest23	T	1	
7	26	2	Broad-leaved deciduous forest	EU-N-Forest24	T	1	
8	27	2	Broad-leaved deciduous forest	EU-N-Forest25	T	2	
9	31	2	Broad-leaved deciduous forest	EU-N-Forest5	T	2	
10	94	2	Tropical deciduous forest and woodland	Fujiwara Sensei-1	V	4	
11	95	2	Secondary broad-leaved deciduous forest in evergreen zone	Fujiwara Sensei-2	V	1	
12	1	2-3	Broad-leaved deciduous forest B	B2-3B	V	3	
13	2	2-5	Broad-leaved deciduous forest C	B2-5A	V	3	
14	3	2-5	Broad-leaved deciduous forest D	B2-5B	V	2	
15	4	3-1	Needle-leaved evergreen forest B	Box3-1-B_FTEST	V	1	55
16	23	3	Needle-leaved evergreen forest	EU-N-Forest20	T	11	
17	24	3	Needle-leaved evergreen forest	EU-N-Forest21	T	1	
18	28	3	Needle-leaved evergreen forest	EU-N-Forest26	T	2	
19	73	3	Needle-leaved evergreen forest C	A65	T	11	
20	5	3-3	Needle-leaved evergreen forest C	B3-4-B	V	17	
21	62	3-4	Conifer Plantations (e.g. *Cryptomeria, Chamaecyparis, Pinus*)	EUV-N-3-5	V	12	

22	7	4-2	Needle-leaved deciduous forest C	B4-2-PK	V	3	23
23	29	4	Needle-leaved deciduous forest	EU-N-Forest27	T	8	
24	74	4	Needle-leaved deciduous forest	A69	T	12	
25	46	6	Scrub vegetation	EU-N-Shrub1	T	10	136
26	47	6	Scrub vegetation	EU-N-Shrub2	T	9	
27	48	6	Scrub vegetation	EU-N-Shrub3	T	5	
28	49	6	Scrub vegetation	EU-N-Shrub4	T	39	
29	50	6	Scrub vegetation	EU-N-Shrub5	T	23	
30	51	6	Scrub vegetation	EU-N-Shrub6	T	3	
31	86	6	Scrub vegetation A	V07P	S	10	
32	87	6	Scrub vegetation B	V08P	S	5	
33	88	6	Scrub vegetation C	V09P	S	4	
34	55	6-1	Scrub in Evergreen-Broadleaf region (substitute vegetation)	EUV-6-2_2	V	11	
35	56	6-1	Scrub in Evergreen-Broadleaf region (substitute vegetation)	EUV-6-2_3	V	5	
36	63	6-1	Scrub in Evergreen-Broadleaf region (substitute vegetation)	EUV-N-6-2_1	V	4	
37	64	6-1	Scrub in Evergreen-Broadleaf region (substitute vegetation)	EUV-N-6-2_4	V	6	
38	6	6-2	Scrub vegetation	B6-3-F	V	2	
39	65	7-1	Bamboo Forest	EUV-N-7-1	V	12	12
40	89	8	Grassland and Meadows	V10part	S	3	140
41	32	8	Grassland and Meadows	EU-N-Herb1	T	3	
42	33	8	Grassland and Meadows	EU-N-Herb10	T	36	
43	34	8	Grassland and Meadows	EU-N-Herb11	T	20	
44	35	8	Grassland and Meadows	EU-N-Herb2	T	1	
45	36	8	Grassland and Meadows	EU-N-Herb7	T	3	
46	37	8	Grassland and Meadows	EU-N-Herb8	T	5	
47	38	8	Grassland and Meadows	EU-N-Herb9	T	68	
48	66	8-1	Grassland and Meadows (typical temperate grassland)	EUV-N-8-1	V	1	

49	8	9-1	Semi-desert and desert vegetation B	B9-2IS	V	15	35
50	52	9	Semi-desert and desert vegetation	EU-N-Sparse-V-1	T	2	
51	53	9	Semi-desert and desert vegetation	EU-N-Sparse-V-3	T	7	
52	54	9	Semi-desert and desert vegetation	EU-N-Sparse-V-4	T	1	
53	69	9	Semi-desert and desert vegetation	A106	T	4	
54	92	9	Semi-desert and desert vegetation	V23e	S	6	
55	57	10-1	Tundra vegetation (e.g. *Salix, Betula*, evergreen Ericaceae)	EUV-N-10-1	V	9	16
56	58	10-3	Tundra vegetation (generally mixed)	EUV-N-10-3_1	V	4	
57	59	10-3	Tundra vegetation (generally mixed)	EUV-N-10-3_2	V	2	
58	60	10-4	Tundra vegetation (e.g. *Dicentra, Polygonum, Papaver, Minuartia, Saxafraga*)	EUV-N-10-4	V	1	
59	68	11	Wetland	A105	T	11	11
60	39	12	Paddy	EU-N-Paddy4	T	58	110
61	61	12	Paddy	EUV-N-12	V	8	
62	71	12	Paddy (Vietnam)	A115	T	2	
63	76	12	Paddy	A88	T	22	
64	81	12	Paddy A	V01P	S	16	
65	82	12	Paddy B	V02P	S	1	
66	93	12	Paddy C	V3	S	3	
67	9	13	Cropland	EU-N-Crop10	T	19	131
68	10	13	Cropland	EU-N-Crop11	T	18	
69	11	13	Cropland	EU-N-Crop12	T	3	
70	12	13	Cropland	EU-N-Crop4	T	1	
71	13	13	Cropland	EU-N-Crop5	T	5	
72	14	13	Cropland	EU-N-Crop6	T	10	
73	15	13	Cropland	EU-N-Crop9	T	13	
74	70	13	Cropland	A110	T	3	

75	**75**	**13**	**Cropland India A**	**A81**	**T**	**20**	
76	**83**	**13**	**Cropland A**	**V04P**	**S**	**21**	
77	**84**	**13**	**Cropland B**	**V05P**	**S**	**11**	
78	**85**	**13**	**Cropland C**	**V06Part**	**S**	**7**	
79	**40**	**14**	**Bare land**	**EU-N-Sand01**	**T**	**1**	
80	**41**	**14**	**Bare land**	**EU-N-Sand02**	**T**	**1**	
81	**42**	**14**	**Bare land**	**EU-N-Sand03**	**T**	**1**	
82	**43**	**14**	**Bare land (Sand)**	**EU-N-Sand4**	**T**	**1**	
83	**44**	**14**	**Bare land (Sand)**	**EU-N-Sand5**	**T**	**1**	
84	**45**	**14**	**Bare land**	**EU-N-Sand6**	**T**	**1**	
85	**67**	**14**	**Bare land**	**A100**	**T**	**1**	**30**
86	**77**	**14**	**Bare land**	**A95**	**T**	**1**	
87	**78**	**14**	**Bare land**	**A96**	**T**	**1**	
88	**79**	**14**	**Bare land**	**A97**	**T**	**2**	
89	**80**	**14**	**Bare land**	**A98**	**T**	**5**	
90	**90**	**14**	**Bare land**	**V17P**	**S**	**6**	
91	**91**	**14**	**Bare land**	**V18P**	**S**	**8**	
92	**30**	**added**	**Mixed forest**	**EU-N-Forest28**	**T**	**1**	**1**
93	**16**	**added**	**Cropland / other vegetation mosaic**	**EU-N-Crop/others3**	**T**	**1**	
94	**17**	**added**	**Cropland / other vegetation mosaic**	**EU-N-Crop/others4**	**T**	**1**	**13**
95	**18**	**added**	**Cropland / other vegetation mosaic**	**EU-N-Crop/others5**	**T**	**11**	
			Total			**759**	**759**

V: collected by vegetation scientists

S: collected by Hiroshi Sato

T: collected by Ryutaro Tateishi

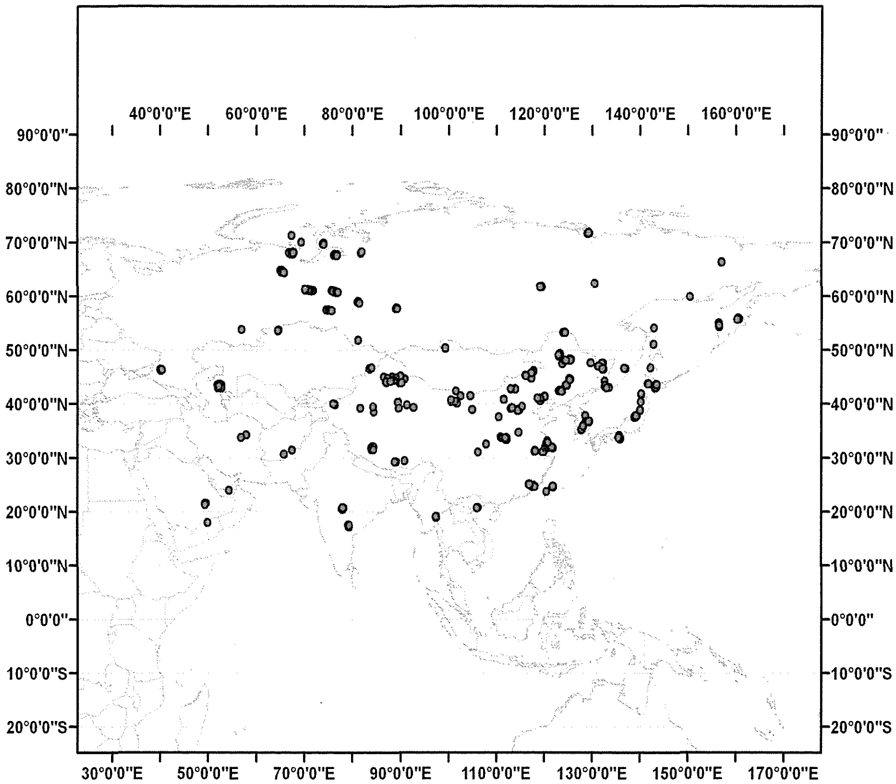


Fig. 3. 1 Distribution of training data

(3) Classification

The maximum-likelihood method of the commercial remote-sensing software package ENVI was applied for vegetation classification of the MODIS data. Bands 1-7 and the Normalized-Difference Vegetation Index (NDVI) derived from Bands 1 and 2 were used for classification.

NDVI = (Band 2 − Band 1) / (Band 2 + Band 1)

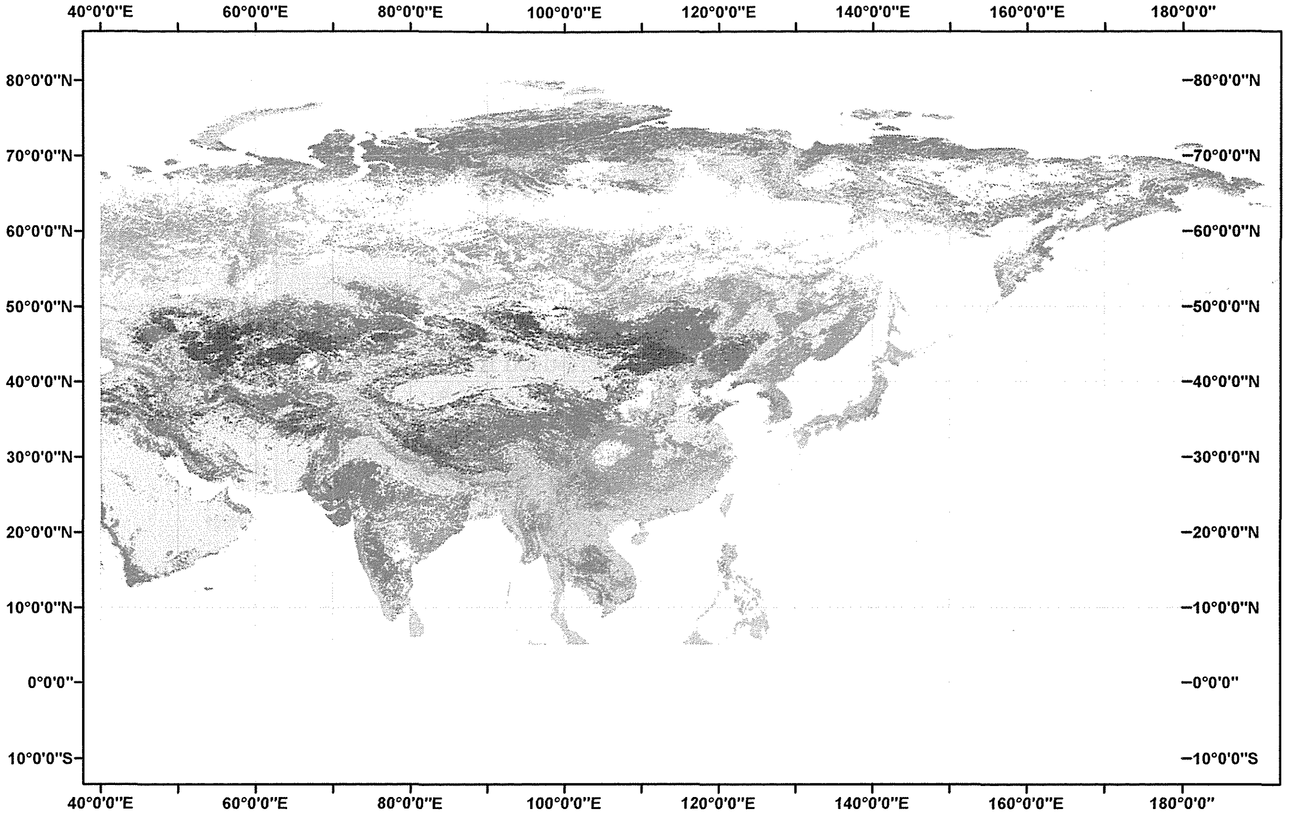
As shown in Table 3.4, the processed MODIS data consist of 23 periods of 16-day composites. Within the 23 periods, periods 1, 4, 7, 10, 13, 16, 19 and 22 were used for classification.

m

C. Vegetation survey results

i Integrated vegetation map

According to the method described in “3. Remote sensing analysis”, the vegetation of Asia was classified using the MODIS data, as shown in Fig.Ci-1.
Fig.Ci-2(1) - Fig.Ci-2(7) shows detailed classification results for 95 training classes. The numbers of the legend items in the figures are the “Class No.” in Table 3.6 (second column from the left).

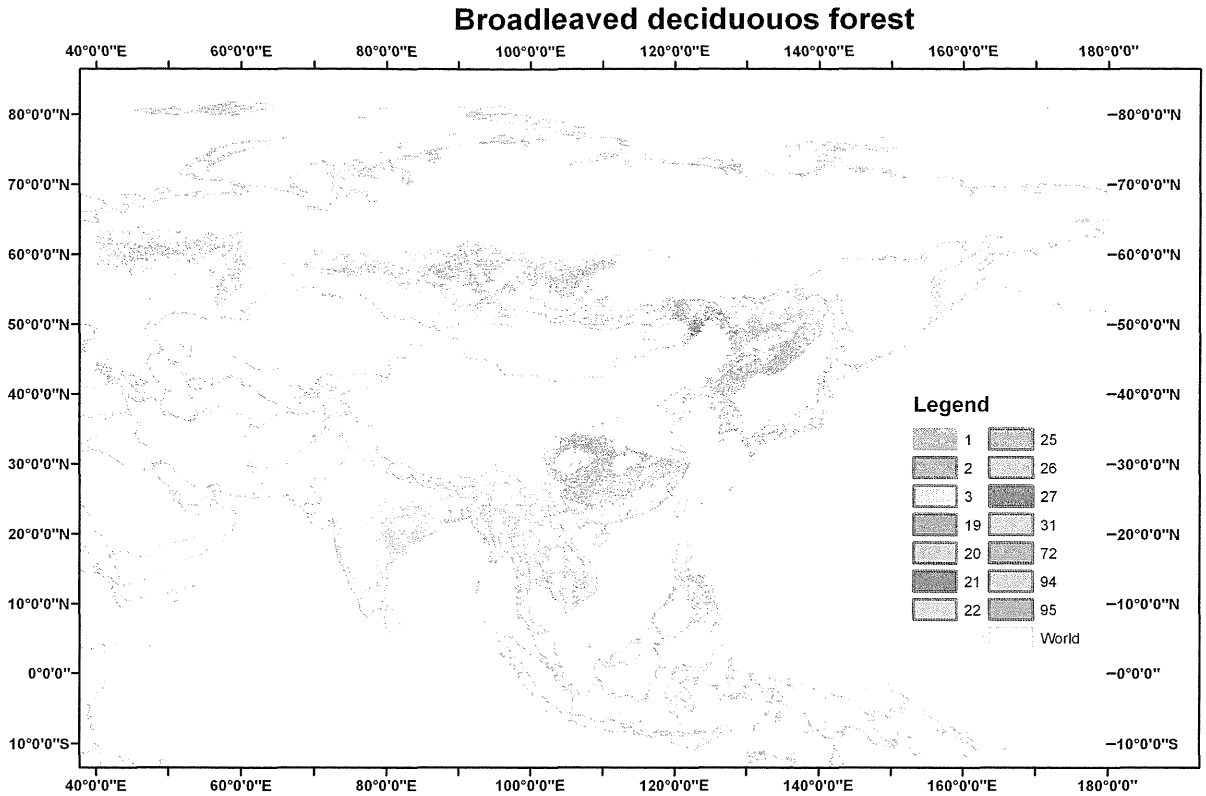


Legend

Broad-leaved deciduous forest (B2)
Needle-leaved evergreen forest (B3)
Needle-leaved deciduous forest (B4)
Scrub vegetation (B6)
Mixed forest (additional)
Bamboo and Sasa stands (B7)
Grassland and Meadows (B8)
Tundra vegetation (B10)
Paddy (B12)
Cropland (B13)
Cropland / other vegetation mosaic (additional)
Wetland (B11)
Semi-desert and desert vegetation (B9)
Bare land (B14)

Symbols in parentheses indicate types in the "Box code" (e.g. B2: Box code 2)
Additional: vegetation classes not included in the Box vegetation classes

Fig. Ci-1 Vegetation map of Asia



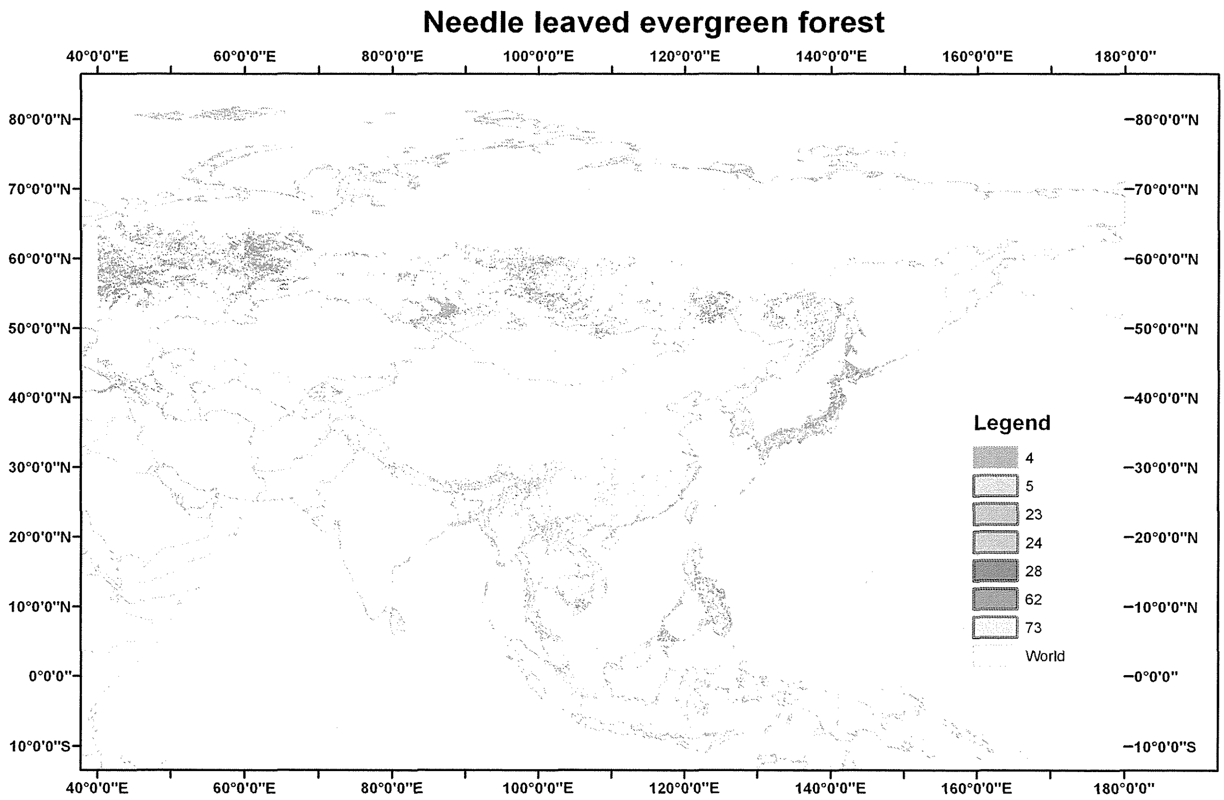
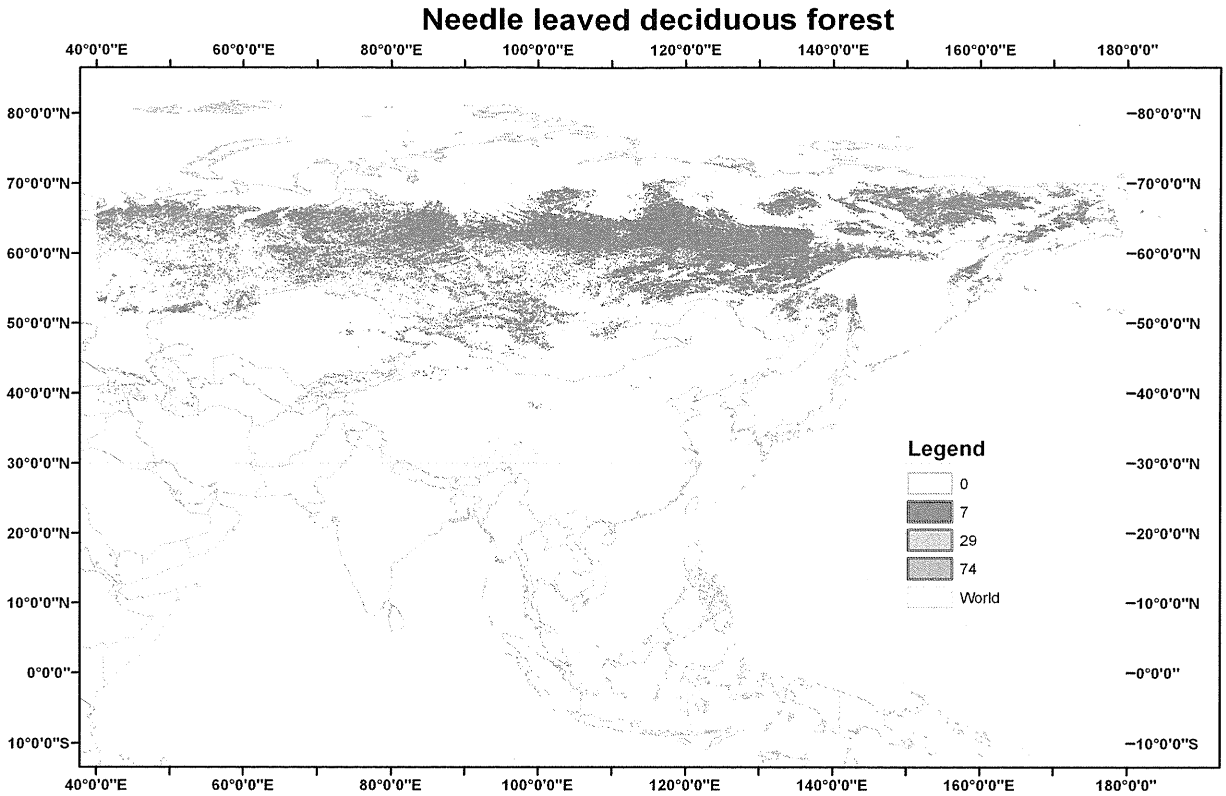


Fig.Ci-2(1) Vegetation map of individual classes



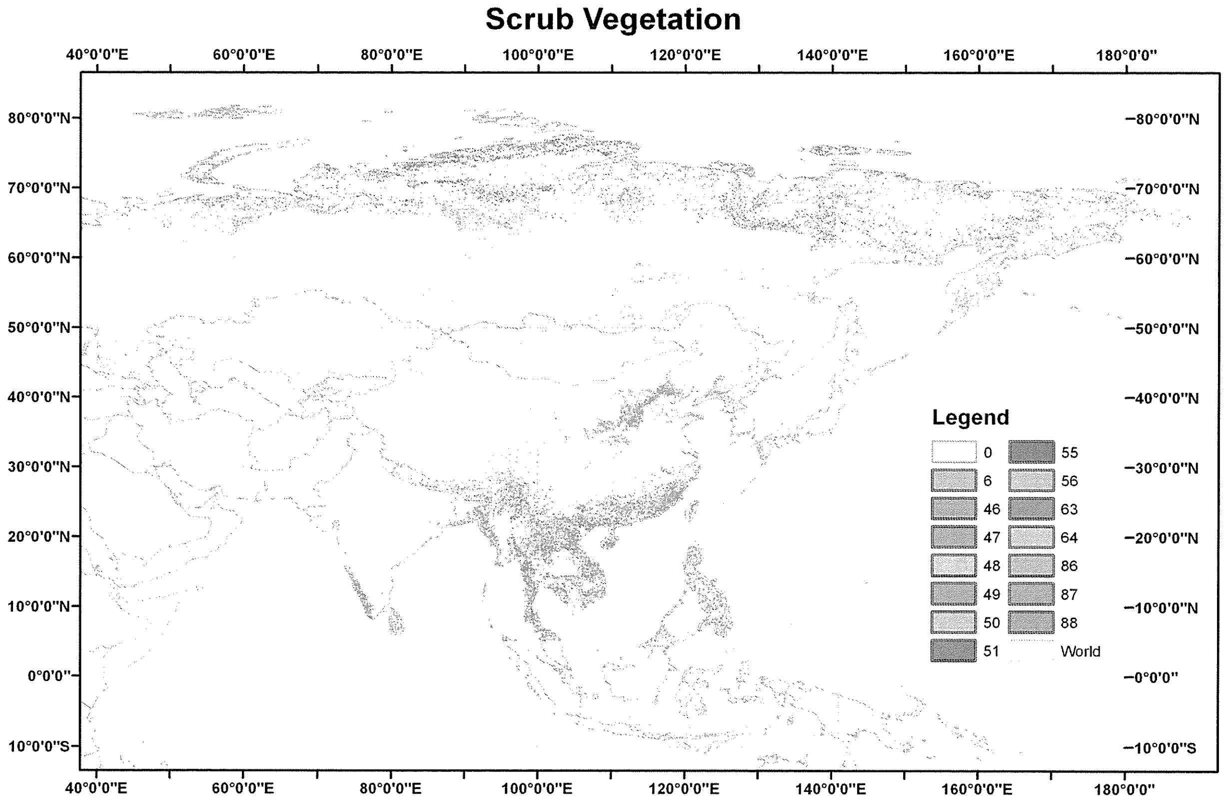
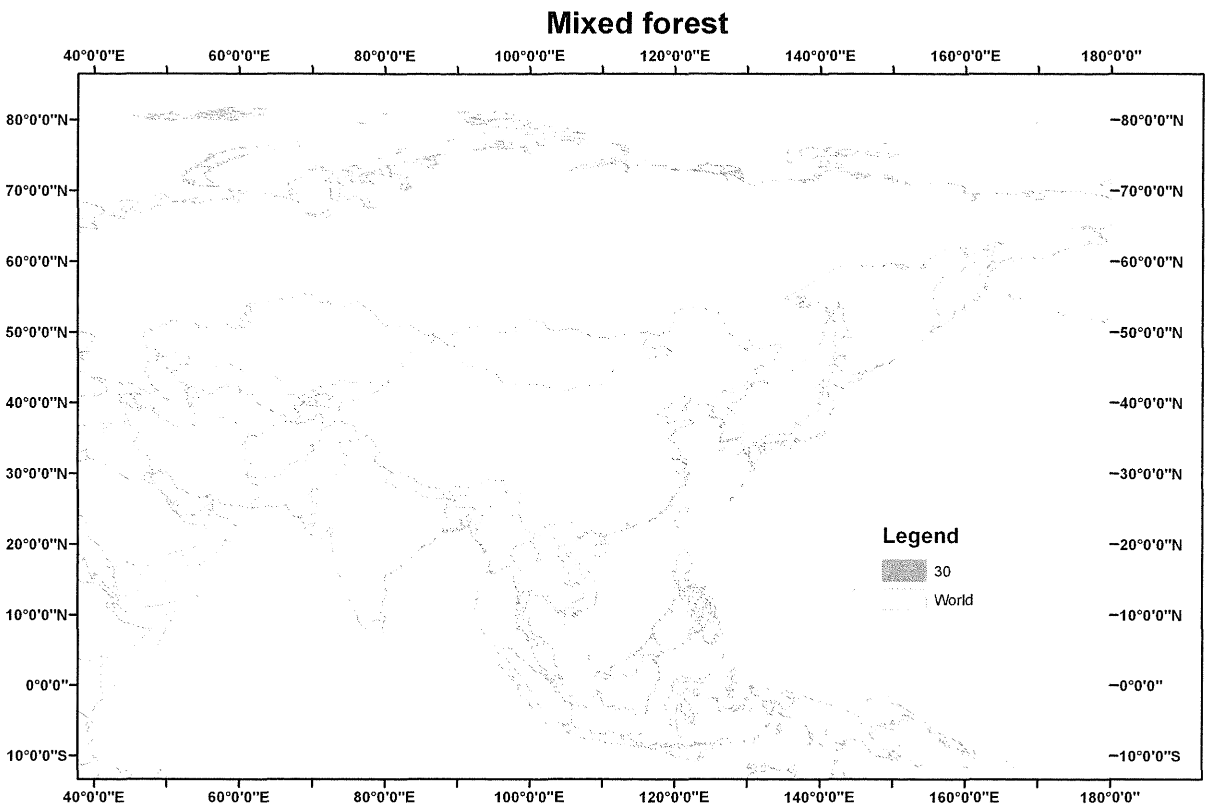


Fig.Ci-2(2) Vegetation map of individual classes



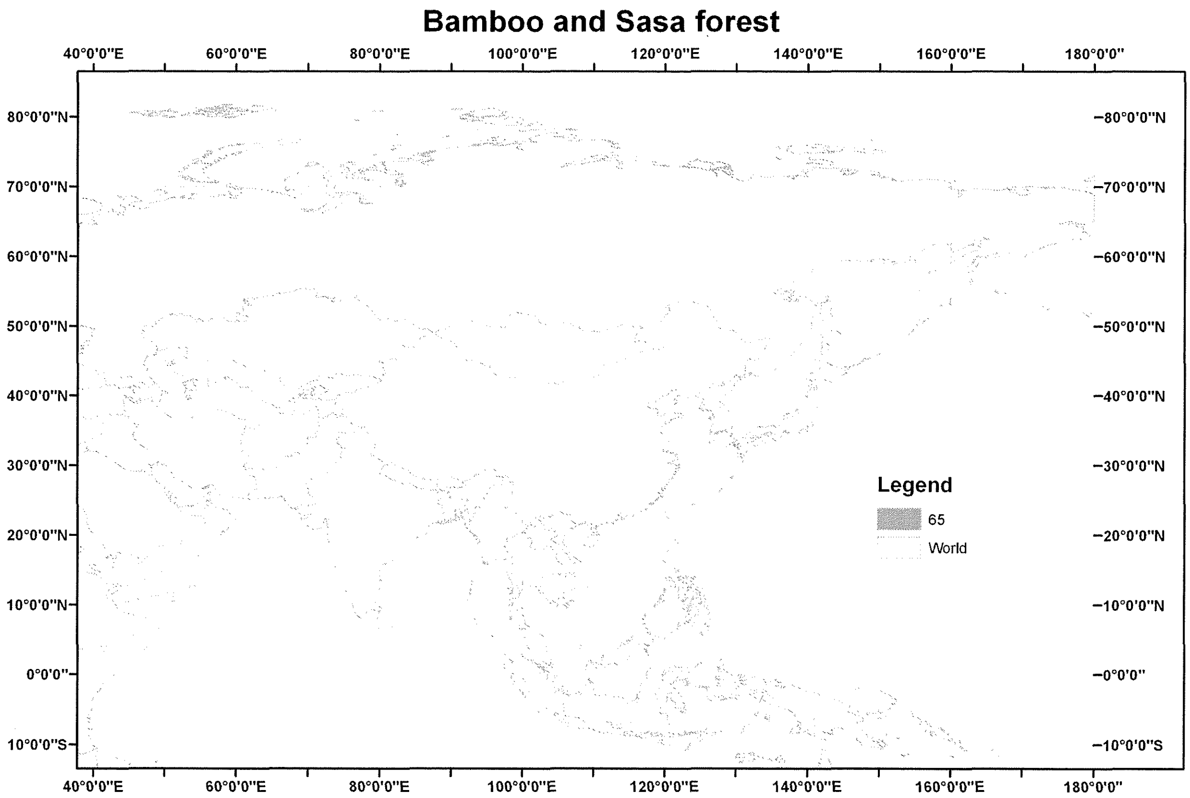
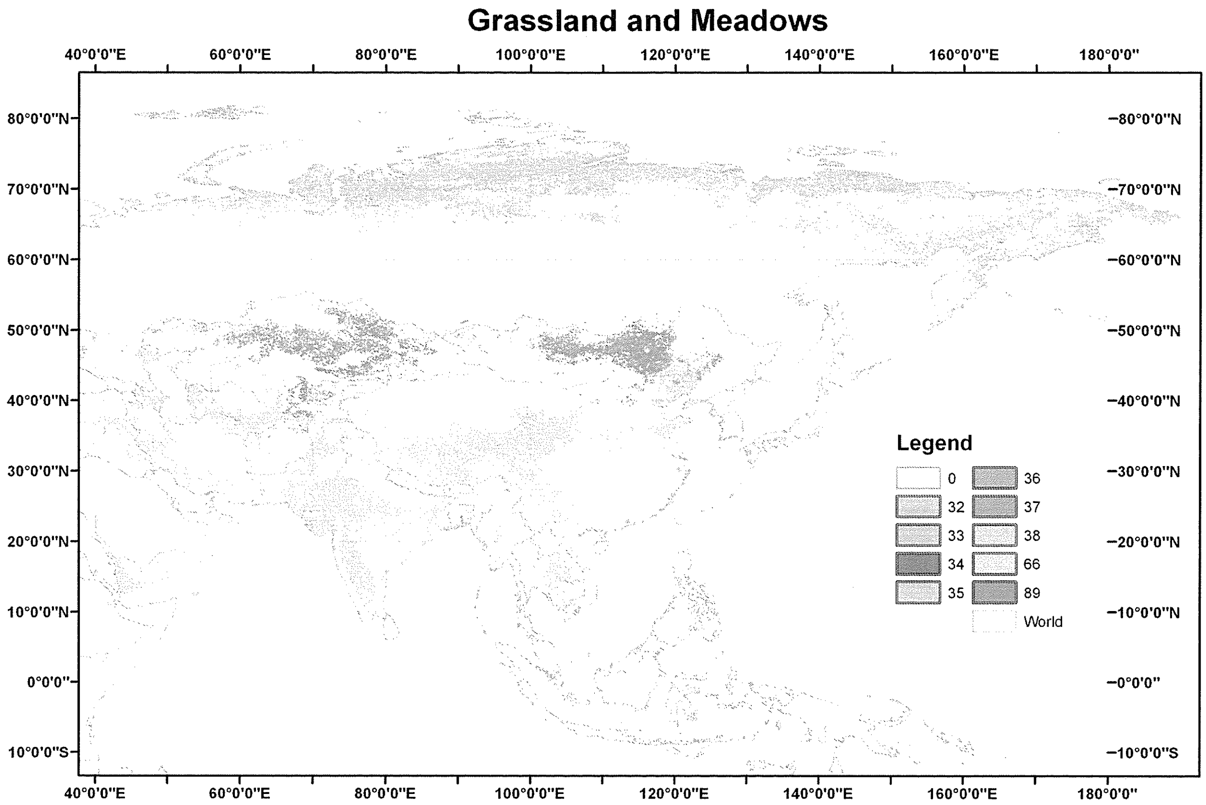


Fig.Ci-2(3) Vegetation map of individual classes



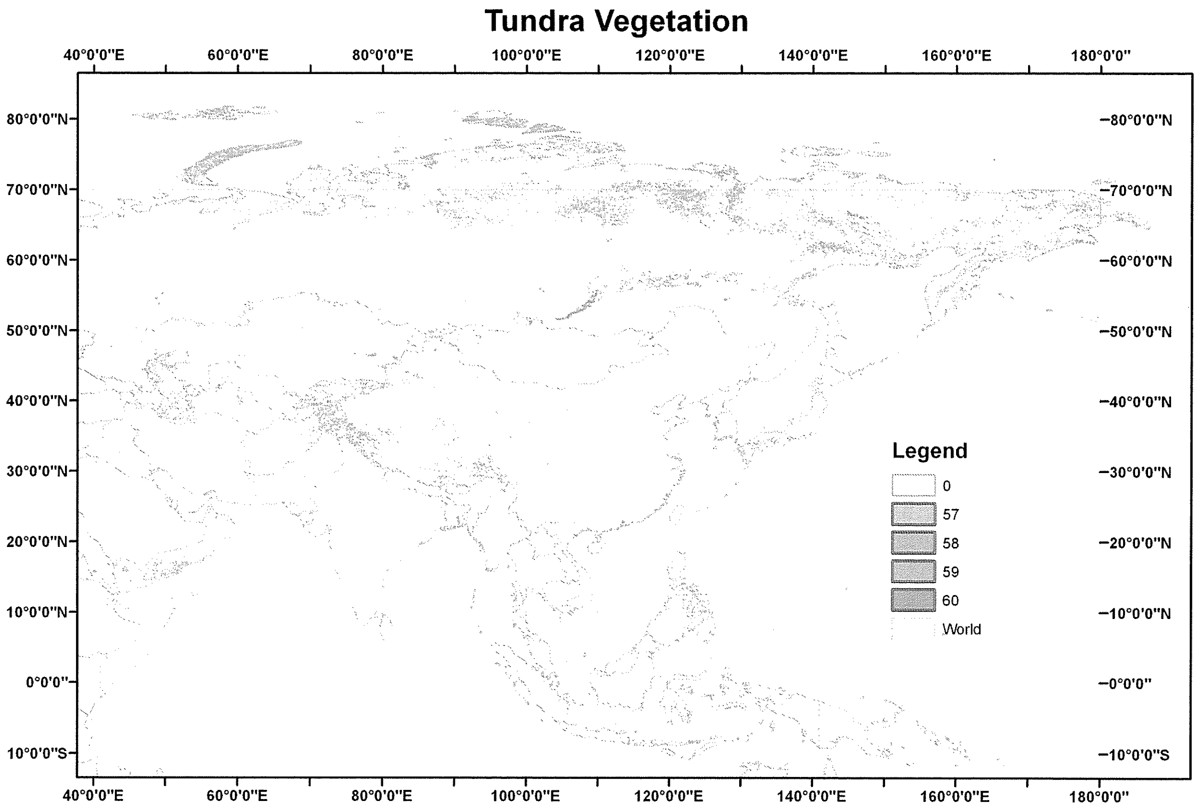
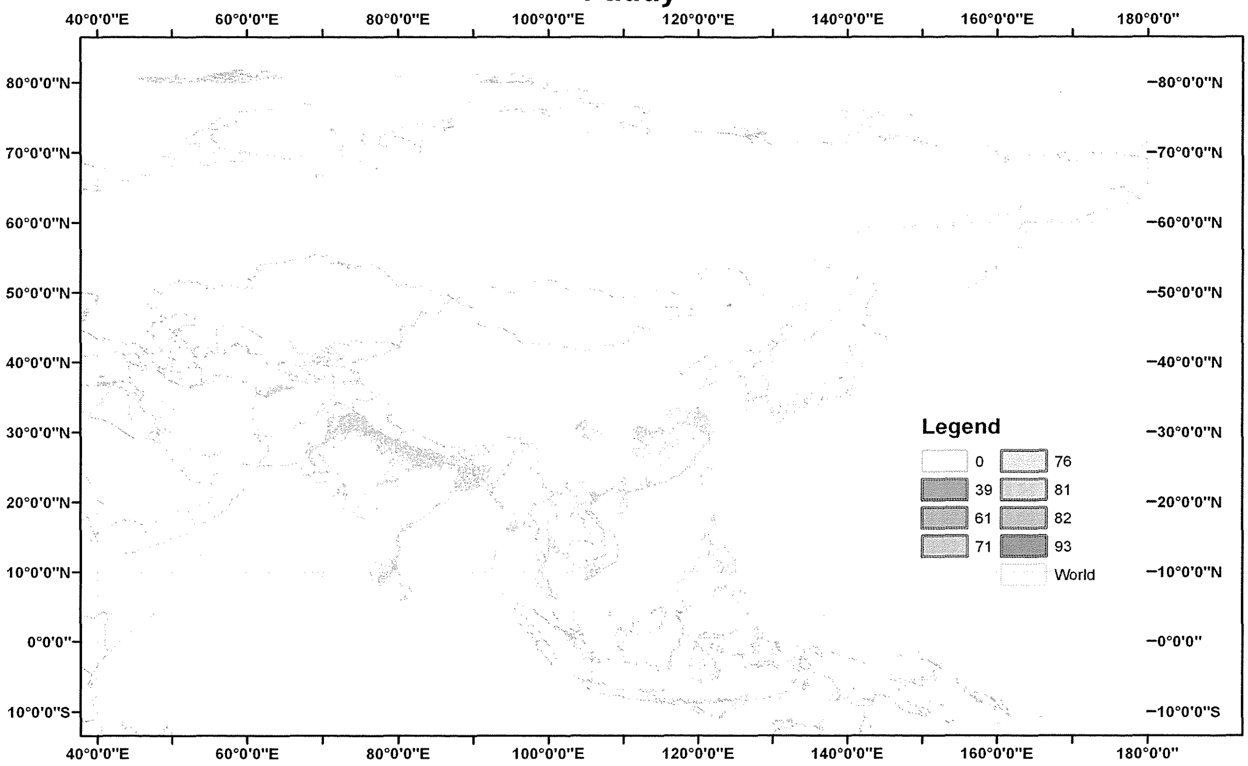


Fig. Ci-2(4) Vegetation map of individual classes

Paddy



Cropland

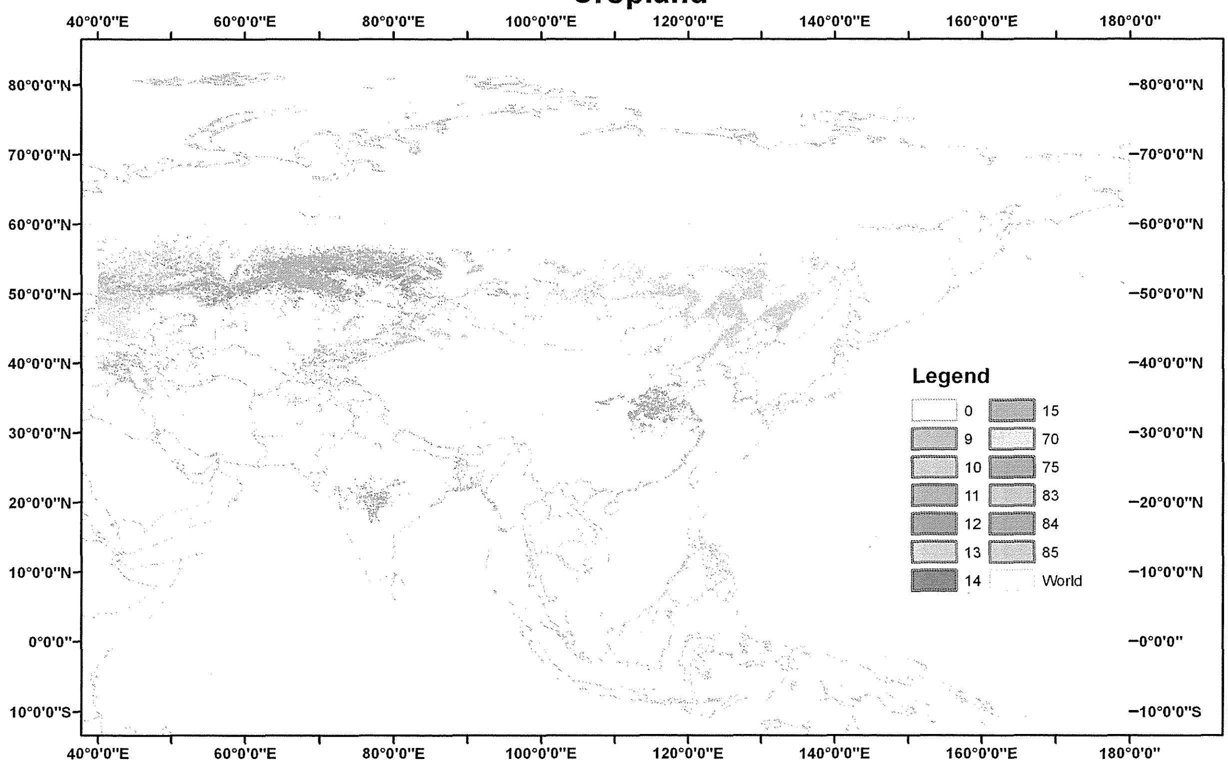
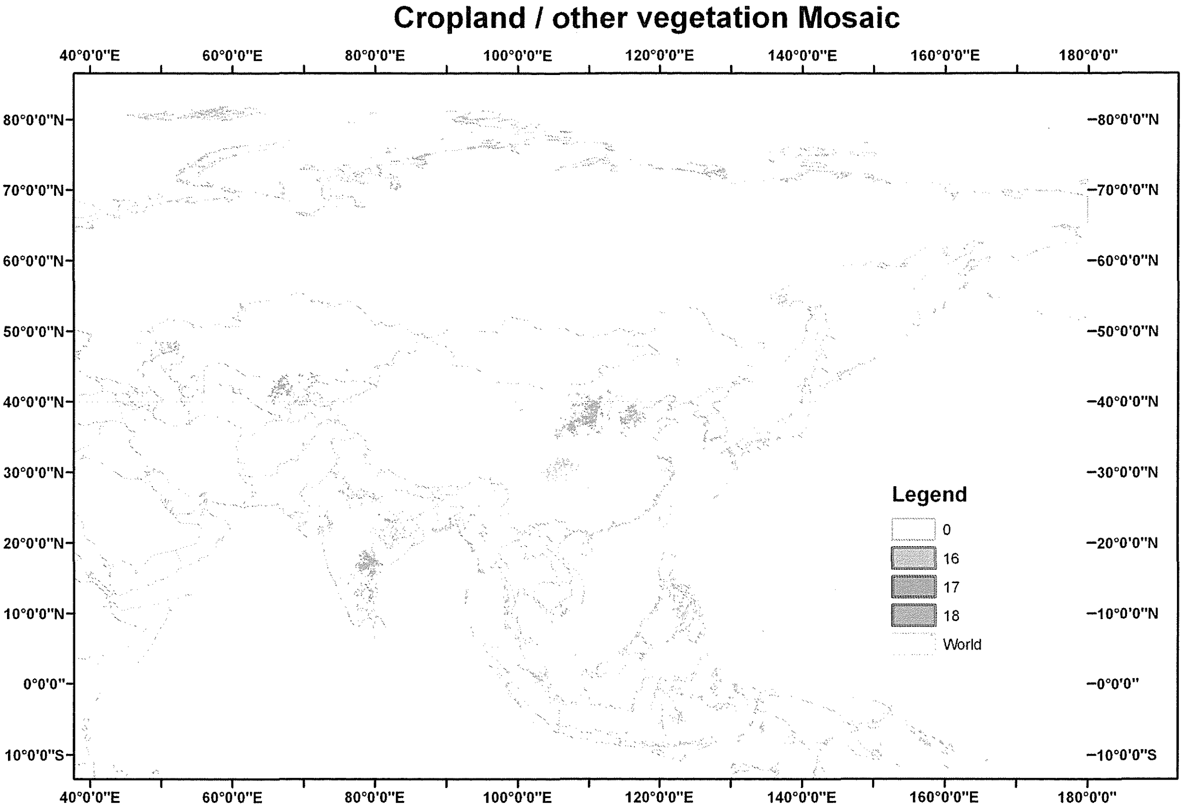


Fig.Ci-2(5) Vegetation map of individual classes



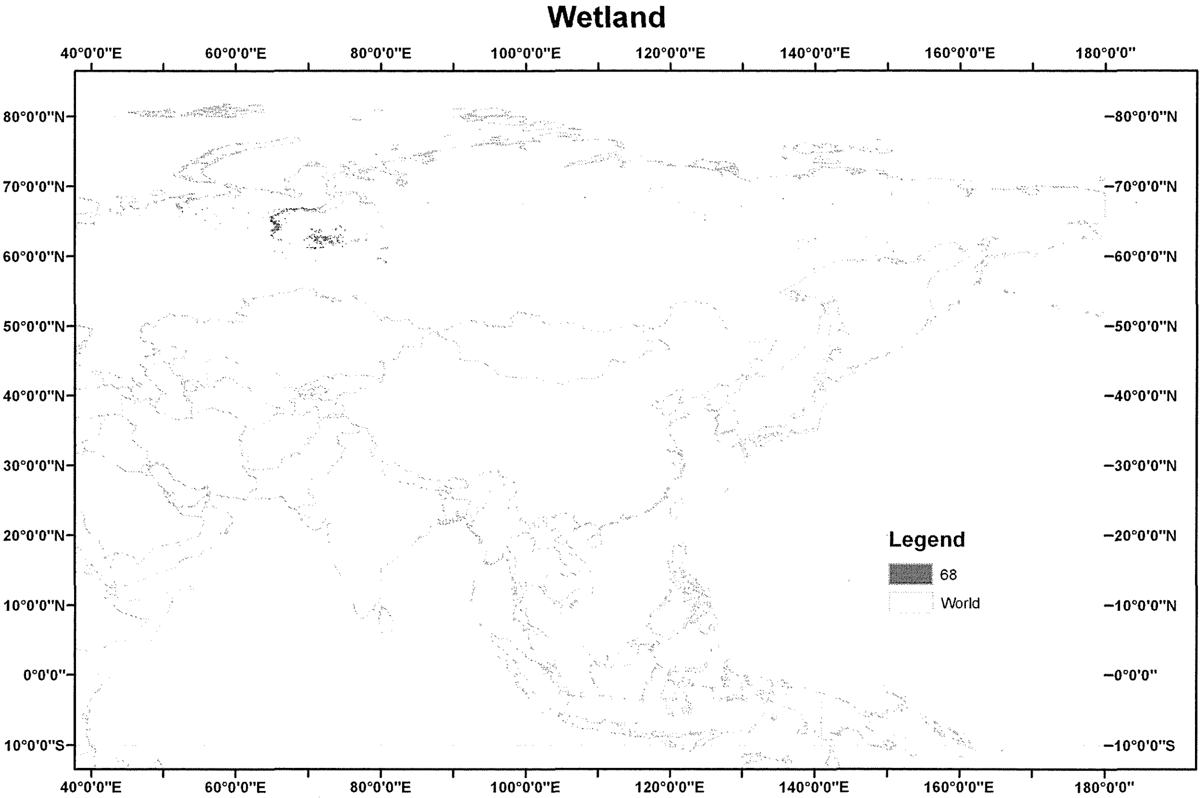
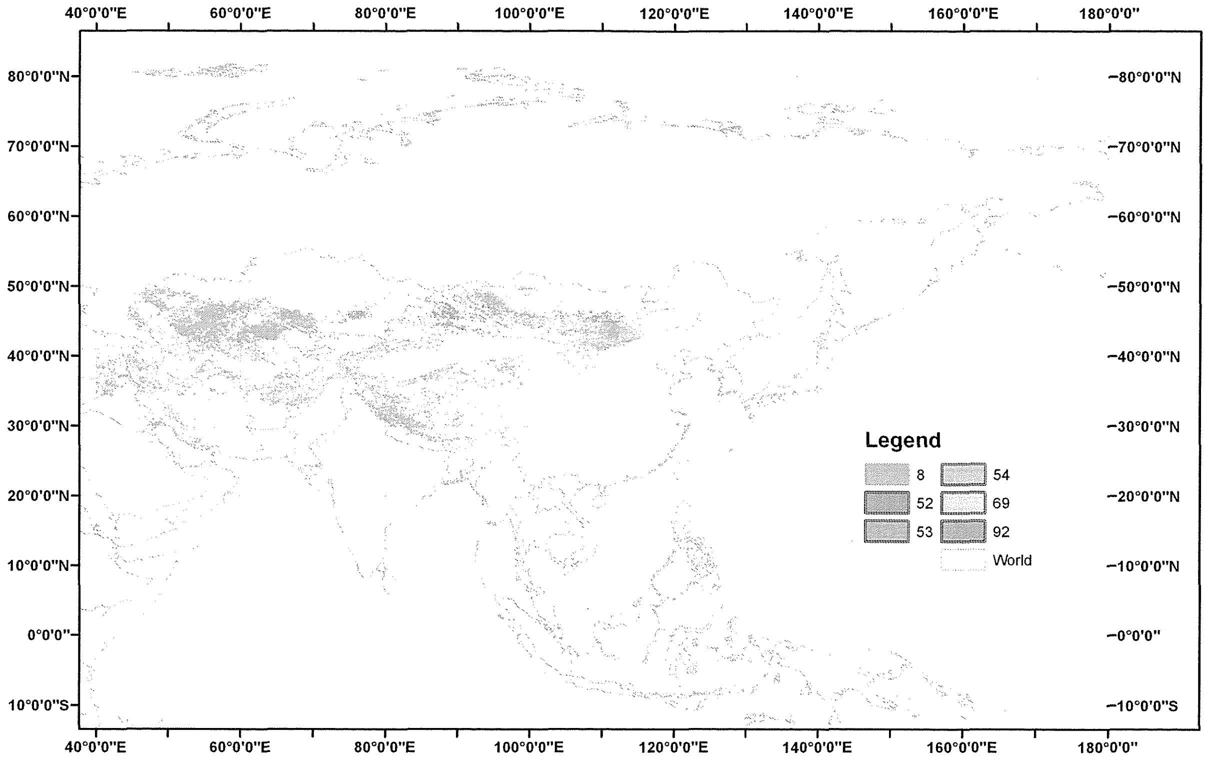


Fig.Ci-2(6) Vegetation map of individual classes

Semi desert and desert vegetation



Bare land

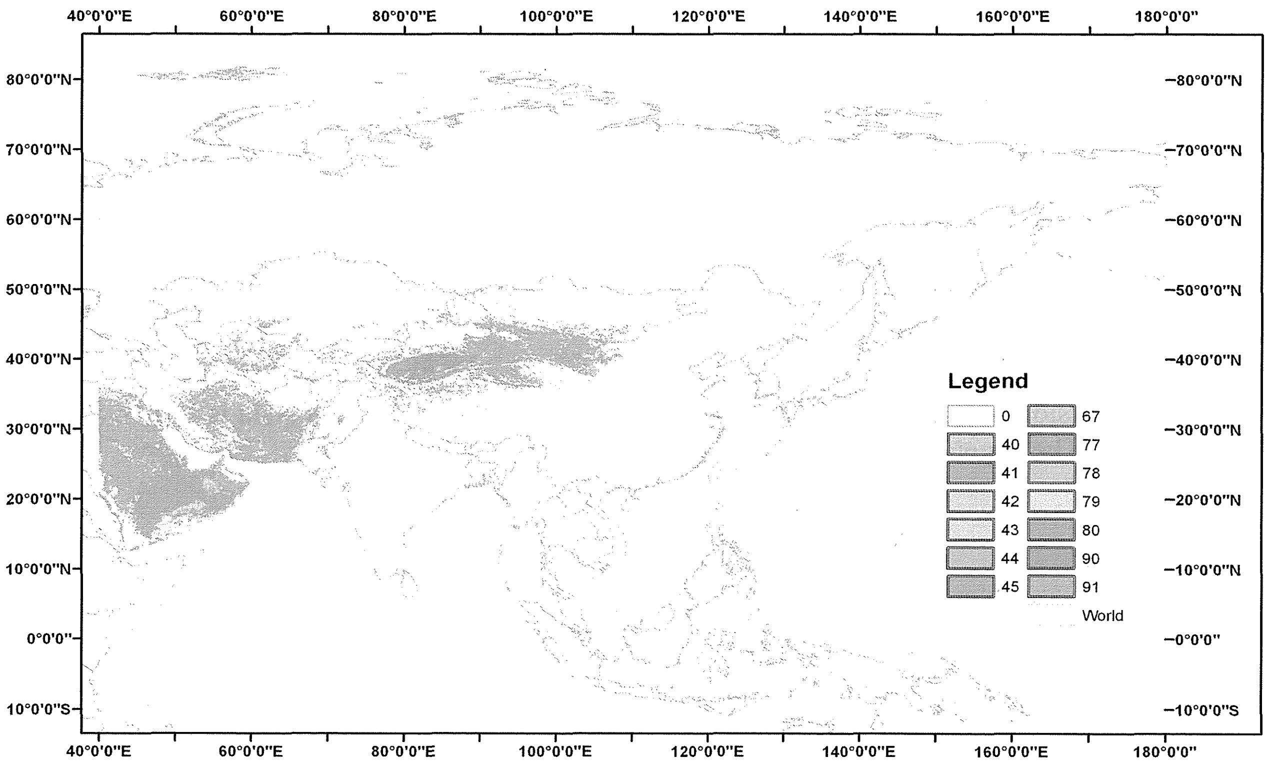


Fig.Ci-2(7) Vegetation map of individual classes

The Figures Ci-2(1) through Ci-2(7) above show detailed classification results for 95 training classes. The numbers shown in the figures represent the "class no." given in the second column from the left in Table 3.6.

Since the classification results shown on the various maps (composite in Figure Ci-1 and individual vegetation types in Figure Ci-2) did not agree very well with some well known vegetation patterns, another methodology was tried. In order to constrain the determination of some vegetation types, source data from the global land-cover map GLCNMO (website: http://www.iscgm.org/) were used as a mask. The discrepancies were especially apparent in the high latitudes. The resulting vegetation map was thus modified as follows.

(1) "Broad-leaved deciduous forest" was divided, based on geographic location, into "Temperate BL-Deciduous (Summergreen) forest" and "Tropical Deciduous Forests and Woodlands".

(2) "Needle-Leaved Evergreen forest (and Woodland)" and "Needle-Leaved Deciduous Forest (and woodland)" were reclassified using the Normalized Difference Vegetation Index (NDVI) of September 2003 from the MODIS data. If September NDVI was larger than 0.45, the vegetation was assumed to be evergreen coniferous and the pixel was assigned to "Needle-Leaved Evergreen Forest"; if smaller than 0.45, the vegetation was assumed to be larch, and the pixel was assigned to "Needle-Leaved Deciduous Forests". With this modification, NL deciduous forest appears in the ultracontinental eastern part of boreal Eurasia and NL evergreen in the less severe western part.

(3) Tundra vegetation was divided into three types: grassy, shrubby and sparse. High-latitude pixels already classified as grassland in Figure Ci-1 were assigned to "Grassy Tundra"; similarly, high-latitude pixels already classified as shrub vegetation in Figure Ci-1 were assigned to "Shrubby Tundra". Pixels identified as sparse vegetation in the northern part of the GLCNMO map were assigned to "Sparse Tundra".

(4) Wetlands in China were added by extracting from Google Earth imagery, with the reference of the "Vegetation Atlas of China" (1:1,000,000; Science Press, Beijing China 2001)

The final version of this first attempt at an Integrated Vegetation Map of Asia is shown on the cover page. The vegetation classes for this final version are shown below.

No.	Vegetation Class	Short Name
1	Evergreen Broad-Leaved Forests	Evergreen BL Forest
2	Deciduous Broad-Leaved Forests and Woodlands	
2.1	Summergreen Deciduous Forests and Woodlands (temperate)	Summergreen Forest/Woodland
2.2	Raingreen Deciduous Forests and Woodlands (tropical)	Raingreen Forest/Woodland
3	Evergreen Needle-Leaved Forests and Woodlands	Evergreen Conifer Forest/Woodland
4	Deciduous Needle-Leaved Forests and Woodlands (Larch)	Larch Forest/Woodland
5	Scrub vegetation	Scrub
6	Grassland and Meadows	Grassland
7	Semi-Desert and Desert Vegetation	Semi-Desert/Desert Vegetation
8	Tundra Vegetation (including alpine)	
8.1	Grassy Tundra	Grassy Tundra
8.2	Shrubby Tundra	Shrubby Tundra
8.3	Sparse Tundra	Sparse Tundra
9	Wetlands	Wetlands
10	Mangrove	Mangrove
11	Paddy Fields	Paddy Fields
12	Cropland	
12.1	Cropland	Cropland
12.2	Cropland Mosaic	Cropland Mosaic
13	Bare Land (no vegetation, including arid desert)	Bare Land
14	Ice Desert	Ice
15	Open Water	Water
16	Urban Areas	Urban

3. Vegetation Maps

a. Some Existing General Vegetation Maps

Elgene O. Box (*Department of Geography, University of Georgia, Athens, Georgia, USA*)

This will be an ongoing project with many products, some in multiple iterations. A major product, the satellite-based Integrated Vegetation Map of Asia, merges national and other more local classifications and maps that were based mostly on fieldwork and geographic inference.

This section lists some of the existing vegetation maps that were known to us early in the process of developing the integrated classification and map. The first, short list is of existing large-area maps made at least partly from satellite data.

Region	Data	Mapping Objective	Publication
World	GVI	vegetation types	Tateishi & Kajiwara 1991
United States	TM	land cover types	Loveland et al. 1991
North America	MODIS	land cover types	Strahler et al. 1999
Europe	?	vegetation types	Eur. Veg. Survey team
East Asia	?	vegetation types	Seong et al. (unpublished)

The early world map by Tateishi & Kajiwara is noteworthy in that it did not put Northern Hemisphere vegetation types into similar geographic positions in the Southern Hemisphere just because the (biologically blind) statistical clustering algorithm suggested similarity. In this sense, this was the first reasonable world vegetation map derived from satellite data. Both it and the North American map, however, suffer from the "high-latitude problem," i.e. the inability to recognize green vegetation (evergreen boreal conifer forest) as far north as it actually occurs due to the low sun angle and low light levels in winter.

Some existing vegetation maps of parts of Asia are identified in the following sections.

1. Soviet Union

The former Soviet Union produced a great many vegetation maps of all or parts of its vast territory, and it is because of this that our Integrated Vegetation Map extends westward into Europe (to the Caucasus, Ukraine, and European Russia). We were able to view many of these existing Soviet-era maps at a team workshop in St. Petersburg (Russia) in 2005, organized by team member Irina Safronova. In the next section (II.3.b), she describes the Russian approach to vegetation mapping in general, especially at broad scales, and provides a lengthy list of maps. At the time of our workshop she also provided the following maps for our use.

Isachenko, T. I., and E. M. Lavrenko (general eds.) and Editorial Group 1974. Karta Rastitel'nosti Evropeyckoy Chasti SSSR [Vegetation of the European Parts of the USSR]. Scale 1:2,500,000 (4 sheets). Akademiya Nauk Soyuza SSR, Botanicheskiy Institut im. V. L. Komarova [Komarov Botanical Institute, Soviet Academy of Sciences], Leningrad.

Isachenko, T. I., and S. A. Gribovoy (content) 1977. Rastitel'nost' SSSR [Vegetation of USSR] (with map of soils on reverse side). Scale 1:25,000,000. In: Bol'shaya Sovyetskaya Entsiklopediya [Soviet Encyclopedia], vol. 24-II. NRKCh GUGK, July 1976, Moskva.

Gribova, S. A., and R. Neuhausl (eds.) 1989. Reconstructed Vegetation of Central and Eastern Europe. Scale 1:2,500,000 (6 sheets plus legend sheets). Published with UNESCO assistance. Komarov Botanical Institute, Russian Academy of Sciences, Leningrad.

"Zony Rastitel'nosti SSSR", 1:5,000,000, 1966, 4 sheets.

"Karta Rastitel'nosti SSSR", 1:4,000,000, 1955, 6 sheets.

2. China

Except for the first entry, the following list is from team member Song Yongchang.

Küchler, A. W. 1948. A new vegetation map of Manchuria. *Ecology*, 29:513-516.

蝴恣刄 (HOU Xueyu) 1960. 中国的植被，附图：中国植被图 (1:800万)，北京：人民教育出版蓙. Vegetation of China. Attachment: Vegetation map of China (1:8,000,000), Beijing: People's Education Publisher.

蝴恣刄 (HOU Xueyu), 胡式之 (HU Shizhi), 陈昌笃 (CHEN Changdu), and 何名这 (HE Miaoguang) 1965. 中国植被图 (1:10,000,000) 及中国植被区划图 (1:15,000,000), 载: 中华人民共和国自然地图集，北京：地图出版蓙. Vegetation map of China (1:10,000,000) and Vegetation regionalization map of China (1:15,000,000). In: [Atlas of China]. Beijing：Geographical Map Press. (In Chinese)

征镒主编 (WU Zhengyi, ed.) 1980.中国植被, 附图：中国植被图 (1:10,000,000), 北京：科学出版蓙 [Vegetation of China]. Attachment: Vegetation Map of China (1:10,000,000). Beijing: Science Press. (In Chinese)

蝴恣刄主编 (HOU Xueyu,ed.) 1982. 中华人民共和国植被图 (1:4,000,000), 北京：地图出版蓙. Vegetation Map of the People's Republic of China (1:4,000,000). Beijing：Geographical Map Press. (In Chinese, with legend in Chinese and English); 1st ed. 1979, with separate legend manual (Chinese and English versions, 12 pp).

HOU Xueyu 1983. Vegetation of China with reference to its geographical distribution. Attachment: Vegetation map of China (1:14,000,000). Annals Missouri Botan. Garden, 70:509-548.

中国科学院中国植被图编辑委员会编 (Editorial Committee for Chinese Vegetation Map, Chinese Academy of Science, ed.) 2000. 中国植被图集 (1:1,000,000), 北京：科学出版蓙. Vegetation Atlas of China (1:1,000,000). Beijing: Science Press. (In Chinese, with English abstract).

3. Japan

A list of vegetation maps made for parts of Japan would be almost endless, but there are relatively few maps of the whole archipelago. One of the best known, though not large, is the following.

Miyawaki, A. 1979. Vegetation und Vegetationskarten auf den Japanischen Inseln. In: *Vegetation und Landscaft Japans*, pp. 49-70. Bulletin of Yokohama Phytosoc. Soc. Japan, vol. 16, (2 maps: potential & actual vegetation).

Some other maps are identified below by Kazue Fujiwara.

Honda, S. 1912. Map of forest zonation (1:8,000,000). In: [*Forest zonation of Japan*] (In Japanese)

Miyawaki, A., and S. Itow 1966. The potential Natural vegetation of Japan (1:9,120,000). In: Phytosociological approach to the conservation of nature and natural resources in Japan, Divisional meeting of Conservation, the 11th Pacific Science Congress, Tokyo.

Suzuki, T. 1966. Vegetation of Japan (ca 1:5,300,000). *Pedologist*, 10(2).

Horikawa, Y. 1968. Vegetation of Japan (1:5000,000). Bulletin of Yasuda Women's University, vol. 2.

Suzuki, T. 1972. Vegetation (1:2,000,000). In: Forest Environment Map of Japan. Society of Forest Environment.

Miyawaki, A., Y. Sasaki, S. Okuda, H. Harada, K. Fujiwara, K. Suzuki and K. Hotta 1974. [Phytosociological examination for construction of environmental protection forests of a school.] Inst. of Environmental Science and Technokogy, Yokohama National University. (In Japanese)

Yoshioka, K. 1974. Vegetation map of Japan. In: *The Flora and Vegetation of Japan*. (M. Numata, ed.).

Miyawaki, A., and S. Okuda 1975. Potential natural vegetation map of Japan (ca 1:4,000,000). In: H. Hamaya 1975. *Nature of Japan* I.

Miyawaki, A., and S. Okuda 1975. Actual vegetation map of Japan (ca 1:4,000,000). In: H. Hamaya 1975. *Nature of Japan* II.

Miyawaki, A., and S. Okuda 1983. Actual vegetation map of Japan (ca 1:6,000,000). In: *Handbook of Japanese Vegetation* (A. Miyawaki, S. Okuda and R. Fujiwara, eds.). Shibundo.

Miyawaki, A., and S. Okuda, K. Fujiwara, K. Suzuki and Y. Sasaki 1983. Potential natural vegetation map of Japan (ca 1:6,000,000).

Miyawaki, A., and K. Fujiwara 1988. Map of the actual vegetation of Japan (ca 10,000,000), in chapter Vegetation Mapping in Japan; in: *Vegetation mapping* (A. W. Küchler and I. S. Zonneveld, eds.). Kluwer Academic Publisher.

4. Other Areas

In addition we also found some of the following maps quite useful.

Region	Author(s)	Publication
Continents (individually)	Eyre 1968	*Vegetation and Soils, a World Picture*
Continents (individually)	Schmithüsen 1976	*Atlas zur Biogeographie*
Arctic	Walker & CAVM Mapping Team 2003	Circumpolar Arctic Vegetation Map (1:7,500,000)
Mongolia	Sokolov et al. 1995	Ecosystems of Mongolia (1:1,000,000)
SE Asia	1964	*Atlas of Southeast Asia*
SE Asia	US Central Intelligence Agency 1970	*Indochina Atlas 1970*
India	Institut Français de Pondichery 1961-	Cartes de la Végétation de l'Inde
Sri Lanka	Fernando 1968	*The Natural Vegetation of Ceylon*

5. World Vegetation from Models

Beginning in the early 1990s it became possible to produce general world maps of potential vegetation regions using climatic envelope or other kinds of models. Experience with this kind of modeling and mapping (see Box 1995) provided the initial draft of the map legend as well as insight and a geographic framework for understanding vegetation-climate relationships in general.

References

Atlas of South-East Asia. 1964. London: Macmillan & Co. Ltd., p. 5-11, 28-29, 42, 47, 55.

Box, E. O. 1995. Global Potential Natural Vegetation: Dynamic Benchmark in the Era of Disruption. In: *Toward Global Planning of Sustainable Use of the Earth -- Development of Global Eco-engineering* (Sh. Murai, ed.), pp.77-95. Amsterdam: Elsevier.

Eyre, S. R. 1968. *Vegetation and Soils, a World Picture*. 2nd ed. Chicago.

Fernando, S. N. U. 1968. *The Natural Vegetation of Ceylon*. Swabhasha, Colombo. 85 pp. + 4 maps.

Institut Français de Pondichery 1961-. Cartes de la Végétation de l'Inde. Travaux Sect. Scient. Techn. Pondichery. (Various sheets completed).

Loveland, T. R., J. W. Merchant, D. O. Ohlen, and J. F. Brown 1991. Development of a land-cover-characteristics data-base for the conterminous US. *Photogram. Engineering & Remote Sensing*, 57:1453-1463.

Okuda, S. 1974. Bibliographie der Vegetationskarten der Japanischen Inseln, Bull. Inst. Environ. Sci. Technol. Yokohama Natn. Univ. 1:123-136. (in Japanese)

Okuda, S. 1976. Bibliographie der Vegetationskarten der Japanischen Inseln (Nachtrag-1), Bull. Inst. Environ. Sci. Technol. Yokohama Natn. Univ. 2:171-179. (in Japanese)

Okuda, S. 1977. Bibliographie der Vegetationskarten der Japanischen Inseln (Nachtrag-2), Bull. Inst. Environ. Sci. Technol. Yokohama Natn. Univ. 3:111-120. (in Japanese)

Schmithüsen, J. 1976. *Atlas zur Biogeographie*. Meyers Grosser Physischer Weltatlas. Bibliographisches Institut, Mannheim.

Sokolov, V. E. et al. 1995. Ecosystems of Mongolia. Scale 1:1,000,000. Joint Russian-Mongolian Complex Biological Expedition. Published with UNEP assistance. Multiple sheets (at least 14).

Strahler, A., and co-workers (no date). MODIS Prototype Classification of North American Land Cover. Map at 1:10,000,000 (analysis: 2 August 1999). Boston University, Geography Department.

Tateishi, R., and K. Kajiwara 1991. Global Land-Cover Classification by NOAA GVI Data: thirteen land-cover types by cluster analysis. In: *Applications of Remote Sensing in Asia and Oceania* (Sh. Murai, ed.), pp. 9-14. Asian Assn. for Remote Sensing, Tokyo University.

US Central Intelligence Agency 1970. *Indochina Atlas 1970*. Directorate of Intelligence, Office of Basic and Geographic Intelligence, p. 78340 8-70, U.S. Central Intelligence Agency.

Walker, D. A., and CAVM Mapping Team 2003. Circumpolar Arctic Vegetation Map. Scale: 1:7,500,000. Conservation of Arctic Flora and Fauna (CAFF) Map No. 1. US Fish and Wildlife Service, Anchorage, Alaska.

b. Zonation and mapping in former Soviet Union

Safronova Irina (*Komarov Botanical Institute of Russian Academy of Sciences, St.-Petersburg, Russia*)

Botanical-geographic maps synthesize data on vegetation cover pronouncedly (markedly) and capaciously. They clearly show the coenotic diversity formed during historical development of territories and the special regularities influenced by modern natural processes as well as changes induced by man's activities. Small-scale maps are a fundamental basis for better understanding of ecological processes.

There are many survey and regional vegetation maps of Russia and neighbouring countries. Among the most significant small-scale maps are:

-

- Map of geobotanical subdivision of the USSR, 1:10 000 000 (Lavrenko, ed., 1947)
- Geobotanical map of the USSR, 1:4 000 000 (Lavrenko, Sochava, eds., 1954)
- Map of botanical-geographic dominions (Lavrenko, 1964)
- Map of World vegetation (Sochava, 1964)
- Vegetation map of Asia (Lukicheva, 1964 a)
- Vegetation map of northern Asia within the USSR (Lukicheva, 1964 b)
- Vegetation map of the South of Eastern Siberia (Belov, ed., 1972)
- Vegetation map of the West Siberian plain (Iljina, ed., 1976)
- Vegetation map of the Arctic (Gribova, 1985)
- Vegetation map of the USSR for higher schools, 1:4 000 000 (Belov and all, 1990)
- Vegetation map of Kazakhstan and Middle Asia, 1:2 500 000 (Lytvinova et al. 1995a,b; Rachkovskaya et al.,2003; Safronova 2004)
- The zones and altitudinal belts (Ogureeva, ed., 1999; Safronova et al., 1999)
- Circumpolar map of the Arctic (2003)
- Vegetation map of Russia 1:15 000 000 (Yurkovskaya and all, 2002, 2006, 2007).

Modern small-scale vegetation maps contain much information, revealing the zonal, altitudinal and regional features of the territories mapped. Zonal (latitudinal) and altitudinal features are determined by changes of solar and thermal climatic conditions. Regional features depend on the degree of climatic continentality. Special attention is given to revealing the topographical diversity of vegetation in relation to physiographic conditions, and to showing vegetation structure and present dynamic status under natural and anthropogenic factors.

Traditionally in the Russian school of geobotanical mapping, the map legends are constructed according to the regional-typological principle (Sochava, 1961, 1979), whereby a multi-level system of subtitles is used that permits the vegetation characteristics to reflect the diversity of environmental conditions and peculiar features of the various regions.

Zonality is the essential geographic regularity to which the natural ecosystems are subordinated. Latitudinal changes of the bioclimatic indices, especially quantity and interrelationships of warm and humidity, determine the zonal regularities of the vegetation cover.

The zone is the largest latitudinal subdivision of the vegetation cover. It reveals itself sufficiently well on relatively flat terrain and is distinguished by dominance of one or several types of vegetation corresponding to the zonal climatic conditions. Of course there are in each zone plant communities that belong to other types of vegetation. Usually these accompany the main type, but they may also dominate locally, as for instance the mire vegetation in the taiga zone of western Siberia.

The subzone is the next highest category and reflects latitudinal changes within the zone. It is distinguished through differences in vegetation typology and structure, and is characterized by definite ecotypes of vegetation, such as pelitophytic types on loamy soils, hemipsammophytic types on loamy sand soils, psammophytic types on sand soils and sands, and hemipetrophytic and petrophytic types on skeletal and stony soils. The composition and participation of these ecotypes are different in the different subzones.

From west to east across Russia, the ecotypes are subjected to regional changes which are characterized by the presence or absence of differential species and by changes of the species' roles in the vegetation cover.

In the territory of Russia and its neighboring countries, from north to south the sequence of vegetation zones is as follows: tundra, taiga, broad-leaved forest, forest-steppe, steppe, semi-desert, and desert.

The tndra zone is represented by four subzones in Russia. Its characteristics features are: the lack of a tree layer; the significant role of small woody plants (shrubs, stlaniks, and dwarf shrubs) which grow slowly, have long lifespans, and are often evergreen; and the high participation of mosses and lichens. The islands of the Arctic Ocean (the Franz-Joseph-Land Archipelago, the northern island of Novaya Zemlya, and the Severnaya Zemlya Archipelago) are occupied by High Arctic Tundra, which is the northernmost type of tundra vegetation. This is dominated by herbaceous perennial vascular plants, but the plant cover is almost fragmentary and considerable areas are covered by ice.

To the south this gives way to typical Arctic tundra, in which a significant role belongs to prostrate dwarf-shrubs, such as species of the genera *Salix*, and *Dryas*. Southward the communities of northern hypo-Arctic tundra with hemi-prostrate dwarf shrubs predominate, and further south this northern hypo-Arctic tundra is replaced by a southern hypo-Arctic tundras with shrub and tussock communities. From west to east, each subzone is divided into geographic variants peculiar to Europe or to West, Central or East Siberia or Chukotka.

In the taiga zone the boreal vegetation of spruce, fir, Siberian dwarf-pine, pine and larch forests predominates. The zone is subdivided into five subzones.

In the northern subzone open woodlands combine with southern hypo-Arctic tundra to produce a forest-tundra subzone, within which six geographic variants are distinguished. In the Europaean forest-tundra, the open woodlands are dominated by spruce widely distributed. In the Siberian sector the larch woodlands cover large areas (*Larix sibirica* in West Siberia, *L. gmelinii* in Central Siberia, and *L. cajanderi* in East Siberia). In Kamchatka the original vegetation is woodlands of *Betula ermanii* .

The north taiga vegetation consists of sparse, needle-leaved coniferous forests with ground covers of dwarf shrubs, lichens and moss under the tree cover. In the west of this subzone the pine forests dominate under spruce forests. In the Ural region spruce forests play the main role. The Siberian north taiga is characterized by the increasing dominance of larch forests, from west to east. In West Siberia the main dominant is *Larix sibirica*, in Central Siberia it is *Larix gmelinii*, and in East Siberia and Chukotka the dominants are *Larix gmelinii* and *L. cajanderi*. In the oceanic climate of Kamchatka Peninsula, *Betula ermanii* is characteristic.

The forests of the middle taiga subzone have ground covers of dwarf shrubs and small herbs and moss. This subzone is the widest in north-south extent. Characteristic features of the taiga in general are expressed most completely in this subzone. The diversity of vegetation cover is presented here by eight geographic variants. In the Ural region, forests of *Pinus sibirica* appear for the first time (eastward), as well as forests with two co-dominants: spruce–fir, Siberian pine–spruce, and Siberian pine–common pine. Dark spruce–Siberian pine coniferous forests predominate in West Siberia. Larch forests prevail east of the Yenisey River: *Larix sibirica* in West Siberia, which gives way further east to *L. gmelinii*. In East Siberia *Betula cajanderi* also plays a notable role. Forests of the Far East are peculiar, with *Larix cajanderi, Betula mandshurica, B. divaricata*, and *Rhododendron dauricum*. The forests of Sakhalin consist of species with limited ranges: *Abies sachalinensis* and *Larix kamtschatica*.

The south taiga subzone is characterized by coniferous forests with a ground layer of nemoral elements. The understorey is more diverse, a layer of herbs and dwarf shrubs is well developed, and the moss cover is fragmentary. There are five geographic variants, differing by distribution of dominant tree species. The southern fringe of the taiga zone (subtaiga zone) is represented in West

Siberia by small-leaved forests with a forb-grass ground layer and in Europe and the Far East by mixed (broad-leaved plus coniferous) and more complicated forests.

In the Ural region the subtaiga differs from that of eastern Europe by the absence of *Fraxinus excelsior* and the presence of *Abies sibirica*, as well as by the eastwardly increasing role of *Tilia cordata*. West Siberian subtaiga contains *Betula pendula* and *Populus tremula*. The East-Siberian subtaiga is richer than that of Central Siberia and contains *Quercus mongolica* and *Betula davurica*, which appear together with *Pinus sylvestris* and *Larix gmelinii*. The Far East (Manchurian) subtaiga has a special composition of tree species: *Picea ajanensis*, *Abies nephrolepis*, *Quercus mongolica* and *Betula davurica*.

To the south of the taiga zone is the broad-leaved forest zone, with forests of beech, oak, hornbeam-oak, and lime (basswood), with or without participation of coniferous trees. This zone extends across European Russia up to the Ural Mountains, is missing in Siberia, and then appears anew in the Russian Far East. In the west of this zone, *Quercus robur*, *Carpinus betulus* and *Fagus sylvatica* are important in these forests, while in eastern Europe the beech and hornbeam are absent, with greater importance of *Quercus robur, Acer platanoides, Fraxinus excelsior* and *Tilia cordata*. The importance of *Tilia* increases in the Trans-Volga region. The Far East forests include the main Manchurian species: *Quercus mongolica, Tilia amurensis*, and *Pinus koraiensis*.

The forest-steppe zone is a combination of meadow-steppes and forests, which often interdigitate in complex mosaics. The forests are broad-leaved in European Russia (*Quercus petraea* and *Carpinus caucasica*) and in the Far East (*Quercus mongolica* and *Tilia amurensis*) but small-leaved (*Betula pendula* and *Populus tremula*) with conifers (*Larix sibirica* and *Pinus sylvestris*) in West Siberia.

South of the forest-steppe zone is the steppe zone. Steppe vegetation includes plant communities of more or less xerophilous, microthermic herbaceous plants. Tufted grasses of the genera *Stipa, Festuca, Agropyron, Koeleria, Poa, Cleistogenes*, and *Helictotrichon* predominate, but forb communities (of genera *Galatella, Tanacetum*, etc.) as well as communities of dwarf semi-shrubs (genera *Artemisia, Thymus*, etc.) and of shrubs (genera *Spiraea, Caragana, Cerasus, Prunus, Amygdalus*, etc.) are also characteristic. Steppe plant communities are predominant.

In the northern steppe subzone, one finds in particular steppes of forbs, *Festuca* and feathergrass. From west to east some species change their phytocoenotical position: east of the Volga River the role of *Stipa zalesskii* and *S. korshinskyi* increases, while *S. ucrainica* disappears. In West Siberia and northern Kazakhstan, *S. kirghisorum* appears. A separate place is taken by Dahurian-Mongolian steppes dominated by *Stipa krylovii, S. baicalensis, Leymus chinensis*, and *Festuca lenensis*.

In the middle subzone, the *Festuca-Stipa* communities are much poorer in forbs, represented here mainly by more xerophilous species.

In the southern steppe subzone, dwarf semi-shrubs occur as co-dominants in the *Festuca-Stipa* communities. Geographic variants are differentiated by one or another wormwood (*Artemisia*) species. In the Caspian region *Artemisia taurica* and *A. lerchiana* are common; in the steppes of the Trans-Volga and western Kazakhstan, *Artemisia lerchiana* and *A. semiarida*; in the steppes of eastern Kazakhstan, *Artemisia sublessingiana* and *A. gracilescens*.

In Russia the desert zone is distinguished only in the Caspian lowland. Its main area is located in Kazakhstan and Middle Asia. Desert vegetation embraces the communities of xerophilous microthermic plants of various growth forms. Dwarf semi-shrubs of the families Asteraceae (genus *Artemisia*, subgenus *Seriphidium*) and Chenopodiaceae (genera *Anabasis, Salsola*, etc.) are the essential growth form in the temperate deserts of the Turanian Basin. These constitute plant communities that occur widely in different habitats: in plains and on mountains slopes; on clay, loam, sandy-loam, scree and stony soils; and on sands, takyrs (dried-clay surfaces), and solonchaks. In the vegetation cover a very important role belongs also to semi-shrubs (genera *Astragalus, Convolvulus, Krascheninnikovia, Salsola,* etc.) and shrubs (genera *Atraphaxis, Calligonum, Caragana, Ephedra, Haloxylon, Salsola*, etc.). These usually grow on stony shallow soils of light mechanical texture and on sands. In the desert communities, ephemeroids (mini-geophytes) and hemi-ephemeroids are often abundant: herbaceous, perennial plants with short vegetative periods (species of genera *Allium, Carex, Poa, Eremurus, Rheum, Tulipa*, etc.). Annual herbaceous plants of the summer-autumn vegetation (genera *Halogeton, Petrosimonia, Salsola, Suaeda*, etc.) are highly typical of temperate deserts, as are ephemerals, the annual herbaceous plants of the spring, autumn-spring or autumn-winter-spring vegetation (genera *Alyssum, Bromus, Eremopyrum, Koelpinia, Tetracme, Veronica*, etc.). In addition, mosses, crustose and fruticose lichens and algae also appear in the vegetation cover.

Widespread throughout the whole territory of the desert zone are *Artemisia* (wormwood), perennial saltwort, and psammophytic shrub communities. Their differentiation according to species composition permits one to distinguish three subzones: the northern, middle and southern. The north desert subzone is dominated by wormwood coenoses . In the Caspian Lowland this is mainly *Artemisia lerchian*, which is replaced further east by *Artemisia semiarida*; it is joined in the area between the Aral Sea and Lake Balkhash by *Artemisia terrae-alba.* In the middle desert subzone both the wormwood and the biyurgun (*Anabasis salsa*) deserts prevail. A large area is occupied by the petrophyte-shrub, psammophyte-shrub and saksa'ul (*Haloxylon*) deserts. *Artemisia terrae-albae* is characteristic of the whole subzone. In the south desert subzone, the saksa'ul and psammophyte-shrub deserts predominate, with wormwood (*Artemisia kemrudica*) and tetyr (*Salsola gemmascens*) coenoses occupying smaller areas.

Huge areas in Asiatic Russia are occupied by mountains. The altitudinal differentiation is the essential regularity of mountain vegetation, which has no analogue in the lowlands. The separate altitudinal belts are formed by plant communities that represent the vegetation types (formation, etc.) as in the lowlands. As an example one may cite the mountain tundra, the mountain taiga and broad-leaved forests, mountain steppes and mountain deserts.

Nival and alpine vegetation are specific (high) mountain types that have no analogues in the lowlands.

The differentiation of altitudinal belts, as well as of lowland vegetation, is determined first of all by the latitudinal position of the mountain uplands, but it also depends on their area, height, role as barrier, steepness, slope direction, etc. The mapping unit for mountain vegetation is the typical altitudinal range or belt, characterizing a definite part of a mountain chain. The mountains of Asiatic Russia are united into several groups of mountain systems: Central Siberian, South Siberian, East Siberian, Chukotkan, Okhotsk-Beringian, Baikal–Dzhukdzhur, Far East, and Kamchatkan.

References

Belov, A. V. (ed.) 1972. [Vegetation map of the South of Eastern Siberia], scale 1 : 1 500 000. Moscow. (In Russian)

Belov, A. V., S. A. Gribova, Z. V. Karamysheva, and T. V. Kotova (eds.) 1990. [Vegetation map of the USSR for higher schools], scale 1 : 4 000 000 (4 sheets). Moscow. (In Russian)

CAVM Team 2003. Circumpolar Map of the Arctic. Scale 1:7 500 000. Conservation of Arctic Flora and Fauna (CAFF). Map No 1 (1 sheet). US Fish and Wildlife Service, Anchorage, Alaska.

Gribova, S. A. 1985. [Vegetation], scale 1 : 10 000 000. In: [*Atlas of the Arctic*], pp 120-121. Moscow. (In Russian)

Iljina, I. S. (ed.) 1976. [Vegetation map of the West Siberian plain], scale 1 : 1 500 000 (4 sheets). Moscow. (In Russian)

Lavrenko, E. M. (ed.) 1947. [Map of geobotanical subdivisions of the USSR], scale 1 : 10 000 000. In: [*Geobotanical Subdivision of the USSR*]. Moscow, Leningrad. Attachment (in Russian).

Lavrenko, E. M. 1964. [Botanical-geographic dominions], scale 1 : 80 000 000. In: [Physiographic Atlas of World], p 65. Maps of World, Arctic and Antarctic. Moscow. (In Russian)

Lavrenko, E. M., and V. B. Sochava (eds.) 1954. [Geobotanical map of the USSR], scale 1 : 4 000 000. Moscow. (In Russian)

Ladygina, G. M., E. I. Rachkovskaya, and I. N. Safronova (eds.) 1995a. Vegetation map of Kazakhstan and Middle Asia (Desert Region). Scale 1 : 2 500 000 (3 sheets). Moscow. (In Russian & English)

Ladygina, G. M., E. I. Rachkovskaya, I. N. Safronova (eds.) 1995b. Vegetation of Kazakhstan and Middle Asia (Desert Region). Explanatory text and map legend. St.-Petersburg. 130pp (in Russian & English).

Lukicheva, A. N. 1964a. [Vegetation of Asia], scale 1 : 25 000 000. In: [*Physiographic Atlas of the World*], pp 110-111. Maps of World, Arctic and Antarctic. Moscow. (In Russian)

Lukicheva, A. N. 1964b [Vegetation of the northern part of Asia within the limits of the USSR], scale 1 : 15 000 000. In: [*Physiographic Atlas of the World*], pp 240-241. Maps of World, Arctic and Antarctic. Moscow. (In Russian)

Ogureeva, G. N. (ed.) 1999. [Zones and types of altitudinal-belt vegetation of Russia and neighbouring countries, for high schools], scale 1 : 8 000 000 (2 sheets). Moscow. (In Russian)

Rachkovskaya, E. I., V. N. Khramtzov, and E. A. Volkova (eds.) 2003. Botanical geography of Kazakhstan and Middle Asia (desert region). St.-Petersburg. 424pp (in Russian & English).

Safronova, I. N. 2004. On phytocoenotical mapping of the Caspian Desert Region. *Annali di Botanica,* n. s., 4:83–93.

Safronova, I. N., and T. K. Yurkovskaya 2007. [Vegetation cover of Pacific Northern Eurasia on geobotanical map], scale 1 : 15 000 000. National Atlas of Russia. In: Proceedings of IV international conference "Plants in monsoon climate", pp 3-5. Vladivostok. (In Russian)

Safronova, I. N, T. K. Yurkovskaya, I. M. Mikljaeva, and G. N. Ogureeva 1999. Zones and types of altitudinal belts vegetation of Russia and neighbouring countries: Explanatory text and legend to map. Moscow. 64pp (in Russian & English).

Sochava, V. B. 1961. [Problems of classification of vegetation, typology of physiogeographic facies and biogeocoenosies. Classification of vegetation and geobotanical mapping]. In: Proceedings of Institute of Biology. Problems of vegetation classification. Institute of Biology, Ural Department, Academy of Sciences of USSR. Sverdlovsk. No 27. pp 5–22 (in Russian).

Sochava, V. B. 1964. [Vegetation of the World], scale 1 : 60 000 000. In: [*Physiographic Atlas of the World*], pp 66-67.. Maps of World, Arctic and Antarctic. Moscow. (In Russian)

Sochava, V. B. 1979. [Vegetation cover on thematic maps]. Novosibirsk. 190pp (in Russian).

Yurkovskaya, T. K., I. S. Iljina, and I. N. Safronova 2002. [Macrostructure of vegetation cover of Russia: map analysis]. In: Geobotanical Mapping 2001–2002, pp 3-15. St.-Petersburg. (In Russian)

Yurkovskaya, T. K., I. S. Iljina, and I. N. Safronova 2006. [Vegetation Map of Russia], scale 1 : 15 000 000. In: [National Atlas of Russia], vol. 1.. Moscow. (In Russian)

III. Results

A. Vegetation survey results
a. Arctic and Boreal zones
1) Alpine Tundra

Yukito NAKAMURA (*Tokyo University of Agriculture, Sakuragaoka 1-1-1, Setagaya-ku, Tokyo 156-8502, Japan*)
Pavel V. KRESTOV (*Institute of Biology & Soil Science, Vladivostok 690022, Russia*)
Ken Sato (*Hokkai-Gakuen University, Sapporo, Japan*)

Abstract
In the middle and northern temperate zones and the boreal zone in Asia, Alpine Tundra occurs in the alpine belt above the timber line, which is delimited by cryophilic factors. In continental central Asia, natural meadows (not including alpine tundra) occur widely as semi-desert or steppe, which are limited by ombrotrophic factors. In Asia the physiognomy of the alpine tundra is dominated by dwarf-shrubs and short graminoids, which are composed of five general vegetation groups: dwarf-shrub communities, snow-patch communities, wind-exposed meadow communities, semi-desert or bare-land communities and spring-water communities.

Characteristic genera are different in the different geographic sectors: the oceanic, Kuril Islands; sub-oceanic Kamtchatka; the maritime Sea of Japan side; continental Sakhalin, Primorsky, and Hokkaido; and ultra-continental Siberia, especially in eastern Yakutia. Dwarf-shrub communities and snow-patch communities occur in the oceanic, sub-oceanic and maritime regions. Semi-desert and bare-land communities have different site conditions. In oceanic and sub-oceanic sectors they occur mainly on volcano, thermokarst and soil fractions. However, in continental and ultra-continental sectors they occur on steep slopes and dry avalanches. Wind exposed meadows occur on wind exposed slopes in oceanic, sub-oceanic and maritime regions, however in continental and ultra-continental regions such as Siberia, Inner Mongolia and Tibet they spread as the climax vegetation.

Representative genera in the alpine vegetation types are as follows: *Loiseleuria, Vaccinium, Diapensia, Cassiope, Phyllodoce, Ledum, Arctous, Arcterica,* and *Bryanthus* in the dwarf-shrub communities (Loiseleurio-Vaccinietea); *Phyllodoce, Harrimanella,* dwarf *Salix, Sibbardia, Geum, Anaphalis, Primula, Gentiana, Carex*, and *Lycopodium* in the snow-patch communities (Phyllodoco-Harrimanelletea); *Dryas, Pedicularis, Oxytropis, Hedysarum, Astragalus, Leontopodium, Silene, Lloydia, Gentiana, Kobresia*, and *Carex* in the wind-exposed meadows (Carici-Kobresietea); *Dicentra, Penstemon, Stellaria, Minuartia, Cerastium, Arenaria, Saxifraga, Papaver, Arabis, Draba, Thlaspi, Cardamine, Viola, Dracocephalum, Euphrasia, Saussurea, Sedum, Thymus, Carex, Deschampsia,* and *Agrostis* in the semi-desert or bare-land communities (Dicentro-Stellarietea); and *Cardamine, Ranunculus, Stellaria, Chrysosplenium, Saxifraga, Epilobium, Montia, Androsace* and *Juncus* in the spring communities (Montio-Cardaminetea).

Results

Study area & method

The study areas of alpine tundra were located in temperate, boreal and sometimes tundra regions in eastern Asia. Most Phytosociological data were taken in the summers of 2006 and 2007 (Table 1.). We visited Primorsky (Russia) in 2005; Yakutia and Sakhalin (Russia), Qinghai (China) and Lasa (Tibet) in 2006; and Cherskiy, the Sayany Mountains, and Sikhote-Alin (Russia) in 2007. The timber lines in these regions are at different elevations, but the physiognomy and structure of the alpine tundra were found to be similar. We took vegetation releves according to the method of Braun-Blanquet (1964) and tried to systematize the hierarchy of Asian, mostly eastern Asian alpine tundra. Vegetation hierarchies of these regions are systematized using the Japanese alpine vegetation as the standard. The hierarchy of Japanese alpine vegetation is as follows:

Loiseleurio-Vaccinietea (Cetrario-Loiseleurietea); dwarf-shrub communities
Phyllodoco-Harrimanelletea; snow-patch communities
Carici rupestris-Kobresietea bellardii; wind-exposed meadow communities
Dicentro-Stellarietea nipponicae; semi-desert and bare-land communities
Montio-Cardaminetea; spring-water communities.

General chronology of alpine tundra in Asia

Alpine tundra vegetation is composed of different chronological elements which spread or were isolated through global climatic changes. The biggest events are glacial ages in the diluvial epoch of the Quaternary. Through the glacial ages alpine vegetation moved from north to south mainly along the sea coasts, where there were oceanic climatic conditions. Continental areas became drier in Siberia or covered with glaciers in Alaska. So in the mid-latitudinal oceanic sectors, the alpine tundra found refugia and mixed with endemic alpine floras which originated in this region. During inter-glacial ages the alpine tundra vegetation moved from south to north and from humid oceanic to dry continental and ultra-continental sectors. Since the last glacial age, the Loiseleurio-Vaccinietea, Phyllodoco- Harrimanelletea and Montio-Cardaminetea communities occur in oceanic, sub-oceanic and maritime sectors, and the Carici rupestris-Kobresietea bellardii and Dicentro-Stellarietea nipponicae have spread into the continental and ultra-continental sectors. In temperate mid-latitude Asia, alpine tundra is composed of its own endemic species, as in Tibet. In this region the alpine tundra is connected with temperate steppe vegetation.

Legend for alpine tundra

Vegetation mapping of Asia needs field survey, and the analysis by GIS is based on satellite data. Through the field surveys, three mappable legend items for alpine tundra are recognized as follows.

a: Alpine tundra characterised by Phyllodoco-Harrimanelletea
b: Alpine tundra characterised by Dicentro-Stellarietea nipponicae
c: Alpine tundra characterised by the *Kobresia humilis-Kobresia pygmaea* community

a: Phyllodoco-Harrimanelletea characteristic alpine tundra
Climatic zone; Oceanic, sub-oceanic and maritime sectors of temperate and boreal zones.
Region: Kurils, Kamchatka, Sakhalin, Japanese Archipelago.
Characteristic genera; *Loiseleuria, Vaccinium, Diapensia, Cassiope, Phyllodoce, Ledum, Arctous, Arcterica, Bryanthus*, *Phyllodoce, Harrimanella,* dwarf *Salix, Sibbardia, Geum, Anaphalis, Primula, Gentiana, Lycopodium*, *Dryas, Pedicularis, Oxytropis, Hedysarum, Astragalus, Leontopodium, Silene, Lloydia, Gentiana, Kobresia, Dicentra, Penstemon, Stellaria, Minuartia, Cerastium, Arenaria, Saxifraga, Papaver, Arabis, Draba, Thlaspi, Cardamine, Viola, Dracocephalum, Euphrasia, Saussurea, Sedum, Thymus, Cardamine, Ranunculus, Stellaria, Chrysosplenium, Saxifraga, Epilobium, Montia, Androsace, Bupleurum, Veronica, Thalictrum, Festuca, Agrostis, Deschampsia, Carex* and *Juncus.*
Adjacent syntaxa: Abieti-Piceetalia, Vaccinio-Pinetalia pumilae, Betulo-Ranunculetea acris, Fagetea crenatae, Quercetea mongolicae.
Plant communities of Phyllodoco-Harrimanelletea characteristic alpine tundra:
See Appendix I.

b: Alpine tundra characterised by Dicentro-Stellarietea nipponicae
Climatic zone: Continental and ultra-continental sectors of boreal zone.

Region; Central and eastern Siberia.
Characteristic genera: *Vaccinium, Cassiope, Ledum, Arctous, Dryas, Pedicularis, Oxytropis, Hedysarum, Astragalus, Leontopodium, Silene, Gentiana, Stellaria, Minuartia, Cerastium, Arenaria, Saxifraga, Arabis, Draba, Viola, Dracocephalum, Euphrasia, Saussurea, Sedum, Thymus, Bupleurum, Veronica, Festuca, Agrostis, Kobresia* and *Carex.*
Adjacent syntaxa: Larici-Betuletaria divaricatae, Ledo-Laricetalia cajanderi, Lathyro-Laricetalia cajanderi.

c: Alpine tundra characterised by the *Kobresia humilis-Kobresia pygmaea* community
Climatic zone: Continental sector of temperate zone.
Region: Tibet.
Characteristic genera: *Primula, Gentiana, Oxytropis, Hedysarum, Astragalus, Melilotoides, Silene, Gentiana, Stellaria, Cerastium, Arenaria, Arabis, Draba, Viola, Dracocephalum, Leontopodium, Saussurea, Anaphalis, Sedum, Saxifraga, Chrysosplenium, Androsace, Heteropappus, Rheum, Bupleurum, Veronica, Llyoidea, Carex, Kobresia, Agrostis, Festuca, Stipa* and *Juncus.*
Adjacent syntaxa: Steppe with *Artemisia* spp. and *Stipa* spp.
Alpine tundra characterised by the *Kobresia humilis-Kobresia pygmaea* community:
1: *Draba eriopoda-Cerastium caespitosum* community
2: *Ophioglossum nudicaule-Saussurea kingii* community
3: *Potentilla parvifolia-Arenaria capillaris* var. *glandulosa* community
4: Elymo nutantis-Kobresietum humilis
5: Leontopodio nanumi-Kobresietum pygmaeae
6: Rheumo globulosi-Kobresietum pygmaeae
7: *Cheilanthes argentea-Selaginella tamariscina* community
See Appendix II.

Table 1.
Appendix I
Appendix II

Tab. 1. List of phtosociological materials (Russia/China/Tibet)

Releve Nr.	Community type	Phytosociological hierarchy	Location	Elevation (m)	Zonal type	Date
Sakhalin						06/Aug.
CX-147	Alpine semi-desert	Dicentro-Stellarietea	Nabilskiy Mts.	750	Boreal	2006/8/15
CX-148	Alpine semi-desert	Dicentro-Stellarietea	Nabilskiy Mts.	750	Boreal	2006/8/15
CX-149	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	755	Boreal	2006/8/15
CX-150	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	820	Boreal	2006/8/15
CX-152	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	810	Boreal	2006/8/15
CX-153	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	810	Boreal	2006/8/15
CX-154	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	960	Boreal	2006/8/15
CX-156	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	968	Boreal	2006/8/15
CX-157	Spring water	Montio-Cardaminetea	Mt. Chamga	968	Boreal	2006/8/15
CX-158	Spring water	Montio-Cardaminetea	Mt. Chamga	968	Boreal	2006/8/15
CX-159	Snow patch	Phyllodoco-Harrimanelletea	Mt. Chamga	1003	Boreal	2006/8/15
CX-160	Spring water	Montio-Cardaminetea	Mt. Chamga	1003	Boreal	2006/8/15
CX-161	Tall forbs	Trollio-Ranunculetalia acris	Mt. Chamga	1003	Boreal	2006/8/15
CX-162	Snow patch	Phyllodoco-Harrimanelletea	Mt. Chamga	1030	Boreal	2006/8/15
CX-166	Alpine heath	Cetrario-Loiseleurietea	Mt. Chamga	1200	Boreal	2006/8/15
CX-167	Alpine heath	Cetrario-Loiseleurietea	Mt. Chamga	1210	Boreal	2006/8/15
CX-169	Snow patch	Phyllodoco-Harrimanelletea	Mt. Chamga	1320	Boreal	2006/8/15
CX-170	Alpine heath	Cetrario-Loiseleurietea	Mt. Chamga	1410	Boreal	2006/8/15
CX-171	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1410	Boreal	2006/8/15
CX-172	Snow patch	Phyllodoco-Harrimanelletea	Mt. Chamga	1410	Boreal	2006/8/15
CX-173	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1400	Boreal	2006/8/15
CX-174	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1400	Boreal	2006/8/15
CX-175	Alpine heath	Cetrario-Loiseleurietea	Mt. Chamga	1460	Boreal	2006/8/15
CX-176	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1512	Boreal	2006/8/15
CX-177	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1510	Boreal	2006/8/15
CX-181	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1040	Boreal	2006/8/17
CX-183	Snow patch	Phyllodoco-Harrimanelletea	Mt. Chamga	1080	Boreal	2006/8/17
CX-184	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1095	Boreal	2006/8/17
CX-186	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1005	Boreal	2006/8/17
CX-187	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1005	Boreal	2006/8/17
CX-188	Spring water	Montio-Cardaminetea	Mt. Chamga	1005	Boreal	2006/8/17
CX-189	Alpine heath	Cetrario-Loiseleurietea	Mt. Chamga	1180	Boreal	2006/8/17
CX-190	Spring water	Montio-Cardaminetea	Mt. Chamga	1180	Boreal	2006/8/17
CX-191	Alpine heath	Cetrario-Loiseleurietea	Mt. Chamga	1230	Boreal	2006/8/17
CX-192	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1260	Boreal	2006/8/17
CX-193	Felsen	Asplenietea rupestria	Mt. Chamga	1270	Boreal	2006/8/17
CX-194	Alpine heath	Cetrario-Loiseleurietea	Mt. Chamga	1310	Boreal	2006/8/17
CX-195	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1510	Boreal	2006/8/17
CX-196	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1510	Boreal	2006/8/17
CX-197	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1490	Boreal	2006/8/17
CX-198	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1490	Boreal	2006/8/17
CX-199	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1460	Boreal	2006/8/17
CX-200	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1460	Boreal	2006/8/17
CX-201	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1438	Boreal	2006/8/17
CX-202	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1425	Boreal	2006/8/17
CX-203	Alpine semi-desert	Dicentro-Stellarietea	Mt. Chamga	1400	Boreal	2006/8/17

CX-204	Alpine meadow	Carici-Kobresietea bellardii	Mt. Chamga	1380	Boreal	2006/8/17
CX-205	Alpine heath	Salicetea herbacea	Mt. Chamga	1420	Boreal	2006/8/17
CX-206a	Snow patch	Phyllodoco-Harrimanelletea	Mt. Chamga	1498	Boreal	2006/8/17
CX-206b	Alpine heath	Cetrario-Loiseleurietea	Mt. Chamga	1380	Boreal	2006/8/17
CX-224	Felsen	Asplenietea rupestria	Mt. Baida	418	Boreal	2006/8/20
CX-226	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	470	Boreal	2006/8/20
CX-227	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	480	Boreal	2006/8/20
CX-228	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	470	Boreal	2006/8/20
CX-229	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	490	Boreal	2006/8/20
CX-230	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	500	Boreal	2006/8/20
CX-231	Alpine heath	Salicetea herbacea	Mt. Baida	520	Boreal	2006/8/20
CX-232	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	522	Boreal	2006/8/20
CX-233	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	522	Boreal	2006/8/20
CX-234	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	520	Boreal	2006/8/20
CX-235	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	520	Boreal	2006/8/20
CX-236	Felsen	Asplenietea rupestria	Mt. Baida	520	Boreal	2006/8/20
CX-237	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	550	Boreal	2006/8/20
CX-238	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	562	Boreal	2006/8/20
CX-239	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	570	Boreal	2006/8/20
CX-241	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	570	Boreal	2006/8/20
CX-242	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	573	Boreal	2006/8/20
CX-243	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	573	Boreal	2006/8/20
CX-244	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	573	Boreal	2006/8/20
CX-245	Alpine heath	Cetrario-Loiseleurietea	Mt. Baida	573	Boreal	2006/8/20
CX-246	Alpine heath	Cetrario-Loiseleurietea	Mt. Baida	573	Boreal	2006/8/20
CX-247	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	638	Boreal	2006/8/20
CX-248	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	640	Boreal	2006/8/20
CX-249	Alpine heath	Salicetea herbacea	Mt. Baida	640	Boreal	2006/8/20
CX-250	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	660	Boreal	2006/8/20
CX-251	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	630	Boreal	2006/8/20
CX-256	Alpine semi-desert	Dicentro-Stellarietea	Mt. Baida	670	Boreal	2006/8/21
CX-258	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	665	Boreal	2006/8/21
CX-261	Alpine heath	Salicetea herbacea	Mt. Baida	650	Boreal	2006/8/21
CX-262	Alpine meadow	Carici-Kobresietea bellardii	Mt. Baida	760	Boreal	2006/8/21
CX-266	Felsen	Asplenietea rupestria	Mt. Baida	675	Boreal	2006/8/21
CX-270	Felsen	Asplenietea rupestria	Mt. Baida	532	Boreal	2006/8/21
CX-271	Felsen	Asplenietea rupestria	Mt. Baida	530	Boreal	2006/8/21
CX-272	Felsen	Asplenietea rupestria	Mt. Baida	520	Boreal	2006/8/21
Yakutia						
Ya-21	Alpine meadow	Carici-Kobresietea bellardii	/of campsite/Yakut	625	Boreal	2006/7/28
Ya-22	Alpine meadow	Carici-Kobresietea bellardii	/of campsite/Yakut	625	Boreal	2006/7/28
Ya-27	Alpine meadow	Carici-Kobresietea bellardii	/of campsite/Yakut	630	Boreal	2006/7/28
Ya-29	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	650	Boreal	2006/7/28
Ya-30	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	650	Boreal	2006/7/28
Ya-31	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	650	Boreal	2006/7/28
Ya-32	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	650	Boreal	2006/7/28
Ya-34	Alpine meadow	Carici-Kobresietea bellardii	/of campsite/Yakut	660	Boreal	2006/7/28
Ya-35	Alpine meadow	Carici-Kobresietea bellardii	/of campsite/Yakut	660	Boreal	2006/7/28
Ya-37	Alpine meadow	Carici-Kobresietea bellardii	/of campsite/Yakut	860	Boreal	2006/7/28
Ya-38	Alpine meadow	Carici-Kobresietea bellardii	/of campsite/Yakut	860	Boreal	2006/7/28
Ya-41-a	Summergreen decidu	Ledo-Betuletalia middendorffii	/of campsite/Yakut	780	Boreal	2006/7/28

Ya-41-b	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	635	Boreal	2006/7/28
Ya-53	Alpine heath	Cetrario-Loiseleurietea	/of campsite/Yakut	1230	Boreal	2006/7/30
Ya-59	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-60	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-61	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-62	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-63	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-64	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-67	Torf Moor	Oxycocco-Sphagnetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-69	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-70	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-73	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-74	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-75	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-76	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-77	Torf Moor	Scheuchzerio-Caricetea	/of campsite/Yakut	1247	Boreal	2006/7/30
Ya-78	Alpine semi-desert	Dicentro-Stellarietea	/of campsite/Yakut	1350	Boreal	2006/7/30
Ya-79	Alpine semi-desert	Dicentro-Stellarietea	/of campsite/Yakut	1300	Boreal	2006/7/30
Ya-80	Alpine semi-desert	Dicentro-Stellarietea	/of campsite/Yakut	1300	Boreal	2006/7/30
Ya-81	Alpine semi-desert	Dicentro-Stellarietea	/of campsite/Yakut	1300?	Boreal	2006/7/30
Ya-82	Alpine semi-desert	Dicentro-Stellarietea	/of campsite/Yakut	1350	Boreal	2006/7/30
Ya-84	Alpine semi-desert	Dicentro-Stellarietea	/of campsite/Yakut	1350?	Boreal	2006/7/30
Ya-85	Alpine semi-desert	Dicentro-Stellarietea	/of campsite/Yakut	1350?	Boreal	2006/7/30
Ya-86	Alpine semi-desert	Dicentro-Stellarietea	/of campsite/Yakut	1300?	Boreal	2006/7/30
Ya-87	Alpine heath	Cetrario-Loiseleurietea	:ampsite/Yakutia/sı	1440	Boreal	2006/7/30
Ya-88	Alpine heath	Cetrario-Loiseleurietea	:ampsite/Yakutia/sı	1440	Boreal	2006/7/30
Ya-89	Alpine heath	Cetrario-Loiseleurietea	:ampsite/Yakutia/sı	1440	Boreal	2006/7/30
Ya-91	Alpine heath	Cetrario-Loiseleurietea	:ampsite/Yakutia/sı	1440	Boreal	2006/7/30
Ya-92	Summergreen decidu	Salicetea sachalinensis	Kubume/Yakutia	1050	Boreal	2006/7/31
Ya-97	Alpine meadow	Carici-Kobresietea bellardii	Kubume/Yakutia	1050	Boreal	2006/7/31
Ya-102	Alpine meadow	Carici-Kobresietea bellardii	Kubume/Yakutia	1050	Boreal	2006/7/31
Ya-106	Summergreen decidu	Salicetea sachalinensis	Kubume/Yakutia	890	Boreal	2006/7/31
Ya-107-a	Summergreen decidu	Salicetea sachalinensis	Kubume/Yakutia	890	Boreal	2006/7/31
Ya-109	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	750	Boreal	2006/8/1
Ya-110	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	750	Boreal	2006/8/1
Ya-111	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	750	Boreal	2006/8/1
Ya-112	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	810	Boreal	2006/8/1
Ya-113	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	820	Boreal	2006/8/1
Ya-114	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	820	Boreal	2006/8/1
Ya-119	Summergreen scrub	Ledo-Betuletalia middendorffii	Oymyakon/Yakutia	750	Boreal	2006/8/1
Ya-121	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	865	Boreal	2006/8/2
Ya-122	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	865	Boreal	2006/8/2
Ya-123	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	865	Boreal	2006/8/2
Ya-124	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	890	Boreal	2006/8/2
Ya-125	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	900	Boreal	2006/8/2
Ya-126	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	905	Boreal	2006/8/2
Ya-127	Dry meadow	Prusatilo-Artemisietea commut	Oymyakon/Yakutia	910	Boreal	2006/8/2
Ya-128	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	920	Boreal	2006/8/2
Ya-134	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1408	Boreal	2006/8/3
Ya-135	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1415	Boreal	2006/8/3
Ya-136	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1415	Boreal	2006/8/3
Ya-137	Alpine meadow	Carici-Kobresietea bellardii	Oymyakon/Yakutia	1415	Boreal	2006/8/3

Ya-138	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1420	Boreal	2006/8/3
Ya-139	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1420	Boreal	2006/8/3
Ya-141	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1585	Boreal	2006/8/3
Ya-142	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1585	Boreal	2006/8/3
Ya-143	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1585	Boreal	2006/8/3
Ya-144	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1630	Boreal	2006/8/3
Ya-145	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1650	Boreal	2006/8/3
Ya-146	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1630	Boreal	2006/8/3
Ya-147	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1710	Boreal	2006/8/3
Ya-148	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1630	Boreal	2006/8/3
Ya-149	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1710	Boreal	2006/8/3
Ya-150	Alpine meadow	Carici-Kobresietea bellardii	Oymyakon/Yakutia	1709	Boreal	2006/8/3
Ya-151	Alpine meadow	Carici-Kobresietea bellardii	Oymyakon/Yakutia	1709	Boreal	2006/8/3
Ya-152	Alpine meadow	Carici-Kobresietea bellardii	Oymyakon/Yakutia	1709	Boreal	2006/8/3
Ya-153	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1700	Boreal	2006/8/3
Ya-154	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1700	Boreal	2006/8/3
Ya-155-a	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1700	Boreal	2006/8/3
Ya-155-b	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1700	Boreal	2006/8/3
Ya-156-a	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1705	Boreal	2006/8/3
Ya-156-b	Alpine heath	Cetrario-Loiseleurietea	Oymyakon/Yakutia	1790	Boreal	2006/8/3
Ya-157	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1790	Boreal	2006/8/3
Ya-158	Alpine heath	Salicetea herbacea	Oymyakon/Yakutia	1790	Boreal	2006/8/3
Ya-159	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1790	Boreal	2006/8/3
Ya-160	Alpine meadow	Carici-Kobresietea bellardii	Oymyakon/Yakutia	1709	Boreal	2006/8/3
Ya-161	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1700	Boreal	2006/8/3
Ya-162	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1700	Boreal	2006/8/3
Ya-164	Alpine heath	Salicetea herbacea	Oymyakon/Yakutia	1790	Boreal	2006/8/3
Ya-165	Alpine heath	Salicetea herbacea	Oymyakon/Yakutia	1790	Boreal	2006/8/3
Ya-166	Alpine heath	Salicetea herbacea	Oymyakon/Yakutia	1860	Boreal	2006/8/3
Ya-167	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1860	Boreal	2006/8/3
Ya-168	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1860	Boreal	2006/8/3
Ya-169	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1862	Boreal	2006/8/3
Ya-170	Alpine meadow	Carici-Kobresietea bellardii	Oymyakon/Yakutia	1860	Boreal	2006/8/3
Ya-171	Alpine meadow	Carici-Kobresietea bellardii	Oymyakon/Yakutia	1850	Boreal	2006/8/3
Ya-172	Alpine meadow	Carici-Kobresietea bellardii	Oymyakon/Yakutia	1850	Boreal	2006/8/3
Ya-173	Alpine heath	Salicetea herbacea	Oymyakon/Yakutia	1654	Boreal	2006/8/3
Ya-174	Alpine semi-desert	Dicentro-Stellarietea	Oymyakon/Yakutia	1501	Boreal	2006/8/3
China						
Q-4	Alpine meadow	Carici-Kobresietea	Chinhai/China	3200	Temperate	2006/9/16
Q-5	Alpine meadow	Carici-Kobresietea	Chinhai/China	3213	Temperate	2006/9/16
Q-6	Alpine meadow	Carici-Kobresietea	Chinhai/China	3213	Temperate	2006/9/16
Q-7	Alpine meadow	Carici-Kobresietea	Chinhai/China	3200	Temperate	2006/9/16
Q-11	Alpine meadow	Carici-Kobresietea	Chinhai/China	3461	Temperate	2006/9/17
Q-12	Alpine meadow	Carici-Kobresietea	Chinhai/China	3514	Temperate	2006/9/17
Q-14	Alpine meadow	Carici-Kobresietea	Chinhai/China	3742	Temperate	2006/9/17
Q-16	Alpine semi-desert	Dicentro-Stellarietea	Chinhai/China	3480	Temperate	2006/9/17
Tibet						
T-8	Alpine meadow	Carici-Kobresietea	Lasa/Tibet	4487	Temperate	2006/9/22
T-9	Alpine meadow	Carici-Kobresietea	Lasa/Tibet	4520	Temperate	2006/9/22
T-11	Alpine meadow	Carici-Kobresietea	Lasa/Tibet	4533	Temperate	2006/9/22

T-14	Alpine semi-desert	Dicentro-Stellarietea	Lasa/Tibet	4562	Temperate	2006/9/22
T-15	Alpine meadow	Carici-Kobresietea	Lasa/Tibet	4668	Temperate	2006/9/22
Cherskii						
CH-1	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	308	Boreal	2007/6/23
CH-2	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	317	Boreal	2007/6/23
CH-3	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	317	Boreal	2007/6/23
CH-4	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	331	Boreal	2007/6/23
CH-5	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	352	Boreal	2007/6/23
CH-6	Alpine heath	Cetrario-Loiseleurietea	Cherskii	355	Boreal	2007/6/23
CH-7	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	355	Boreal	2007/6/23
CH-8	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	354	Boreal	2007/6/23
CH-9	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	354	Boreal	2007/6/23
CH-10	Alpine heath	Cetrario-Loiseleurietea	Cherskii	325	Boreal	2007/6/23
CH-10-b	Torf Moor	Oxycocco-Sphagnetea	Cherskii	325	Boreal	2007/6/23
CH-11	Torf Moor	Oxycocco-Sphagnetea	Cherskii	320	Boreal	2007/6/23
CH-19	Alpine heath	Cetrario-Loiseleurietea	Cherskii	189	Boreal	2007/6/24
CH-24	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	331	Boreal	2007/6/24
CH-25	Alpine heath	Cetrario-Loiseleurietea	Cherskii	189	Boreal	2007/6/24
CH-26	Alpine heath	Cetrario-Loiseleurietea	Cherskii	348	Boreal	2007/6/24
CH-27	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	341	Boreal	2007/6/24
CH-28	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	339	Boreal	2007/6/24
CH-54	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	23	Boreal	2007/6/26
CH-55	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	23	Boreal	2007/6/26
CH-56	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	24	Boreal	2007/6/26
CH-57	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	24	Boreal	2007/6/26
CH-58	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	29	Boreal	2007/6/26
CH-59	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	30	Boreal	2007/6/26
CH-60	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	26	Boreal	2007/6/26
CH-61	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	15	Boreal	2007/6/26
CH-63	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	25	Boreal	2007/6/26
CH-64	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	24	Boreal	2007/6/26
CH-69	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	24	Boreal	2007/6/26
CH-70	Alpine semi-desert	Dicentro-Stellarietea	Cherskii	24	Boreal	2007/6/26
CH-71	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	23	Boreal	2007/6/26
CH-72	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	23	Boreal	2007/6/26
CH-74	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	16	Boreal	2007/6/26
CH-76	Alpine meadow	Carici-Kobresietea bellardii	Cherskii	5	Polar	2007/6/28
CH-83	Tundra	Cetrario-Loiseleurietea	Cherskii	28	Polar	2007/6/28
CH-84	Tundra	Carici-Kobresietea bellardii	Cherskii	28	Polar	2007/6/28
CH-85	Tundra	Cetrario-Loiseleurietea	Cherskii	28	Polar	2007/6/28
CH-88	Tundra	Salicetea herbacea	Cherskii	28	Polar	2007/6/28
CH-89	Tundra	Carici-Kobresietea bellardii	Cherskii	28	Polar	2007/6/28
CH-90	Tundra	Salicetea herbacea	Cherskii	28	Polar	2007/6/28
CH-91	Tundra	Salicetea herbacea	Cherskii	28	Polar	2007/6/28
CH-92	Tundra	Salicetea herbacea	Cherskii	17	Polar	2007/6/28
CH-109	Torf moss	Oxycocco-Sphagnetea	Cherskii	5	Polar	2007/6/29
CH-110	Tundra	Salicetea herbacea	Cherskii	10	Polar	2007/6/29
CH-111	Tundra	Salicetea herbacea	Cherskii	10	Polar	2007/6/29
CH-112	Tundra	Salicetea herbacea	Cherskii	17	Polar	2007/6/29
CH-125	Tundra	Salicetea herbacea	Cherskii	17	Polar	2007/6/29
CH-126	Tundra	Ledo-Betuletalia middendorffii	Cherskii	10	Polar	2007/6/29

CH-127	Tundra	Ledo-Betuletalia middendorffii	Cherskii	10	Polar	2007/6/29
CH-128	Tundra	Ledo-Betuletalia middendorffii	Cherskii	15	Polar	2007/6/29
CH-129	Tundra	Salicetea herbacea	Cherskii	15	Polar	2007/6/29
CH-130	Tundra	Salicetea sachalinensis	Cherskii	20	Polar	2007/6/29
CH-131	Tundra	Dicentro-Stellarietea	Cherskii	20	Polar	2007/6/29
CH-133	Tundra	Salicetea herbacea	Cherskii	18	Polar	2007/6/29
CH-134	Tundra	Dicentro-Stellarietea	Cherskii	15	Polar	2007/6/29
CH-135	Tundra	Dicentro-Stellarietea	Cherskii	15	Polar	2007/6/29
CH-136	Tundra	Dicentro-Stellarietea	Cherskii	15	Polar	2007/6/29

Appendix 1

Biogeographical Diversity of Alpine Tundra Vegetation in the Oceanic Regions of Northeast Asia

Yukito NAKAMURA (Tokyo University of Agriculture, Sakuragaoka 1-1-1, Setagaya-ku, Tokyo 156-8502, Japan)
Pavel V. KRESTOV (Institute of Biology & Soil Science, Vladivostok 690022, Russia)

Abstract

The Arctic tundra zone and alpine vegetation belt are characterized by a complex of dwarf-shrub, graminoid and herbaceous tundra communities that occur in conditions of heat deficit and a very short growing season. The effects of these climatic factors in different habitats are strongly controlled by topography. Generally, tundra plant communities occupy their own microhabitats with peculiar environmental conditions that create the highly diverse vegetation mosaic in alpine belts. In oceanic regions of Northeast Asia, alpine vegetation occurs from the temperate to boreal zones of Japan and Russia. This paper focuses on the most peculiar representatives of six alpine vegetation classes. Phytosociological diversity of tundra communities is described, in first approximation, with special reference to their biogeographical distributional patterns.

Introduction

According to traditional understanding of vegetation zonation in northern Asia, tundra, as a vegetation type, is characteristic to polar deserts and Arctic tundra zones and to the upper vegetation belts of large mountain systems in the temperate, boreal and subarctic zones.

In northeastern Asia, only Wrangell and Gerald Islands are in the zone of Arctic Deserts (KOLESNIKOV 1961), which are characterized by lack of a closed vegetation cover. Large areas on these islands are covered by talus or rock outcrops. Crustose and foliose lichens (species of *Gyrophora, Lecidea,* and *Rhizocarpon*) are most abundant on the rocky substrates. On sites with accumulations of fine soil, a spare vegetation cover is formed by fruticose lichens (*Alectoria, Cetraria* and *Cladonia*) and mosses (mainly *Andraea papillosa, Pogonatum capillare, Rhacomitrium lanuginosum* and *Tetraplodon mnioides*). Vascular plants are represented by *Douglasia ochotensis, Artemisia glomerata, Papaver polare, Saussurea tilesii, Saxifraga funstonii,* etc. The bryophytes and flowering plants are scattered and not numerous (GORODKOV 1958).

The coast of the Arctic Ocean and all of the Chukotka Peninsula north of 65°N are covered by tundra vegetation. The tundra zone is subdivided into two subzones: typical Arctic tundra along the Arctic coast and lichen tundra as the main zonal vegetation on the Chukotka Peninsula and lower Anadyr River basin (KOZHEVNIKOV 1996). The Far Eastern sectors of the Arctic Polar Desert and Tundra are differentiated from the rest of the circum-Arctic zone by the presence of so-called Beringian plant species, which are also common to Alaskan and eastern-Canadian sectors of the Arctic zone (YURTSEV et al. 1978).

Tundra vegetation is characterized by a closed, one-layer cover composed mainly of perennial plants, especially dwarf-shrubs, mosses and lichens, and by a lack of larger shrubs and trees. Most typical tundra plants have their renewal buds no higher than 20–30 cm above the ground and reproduce mainly vegetatively. All tundra plants are adapted to the short vegetative season with its long period of daylight (KOZHEVNIKOV 1996). Tundra communities vary in composition depending on site edaphic and climatic conditions. Regions along the Arctic coast are characterized by predominance of sedge and heath communities with *Carex* spp., *Eriophorum vaginatum, Vaccinium uliginosum, Betula exilis* and leafy mosses. On the Chukotka Peninsula, sedge communities are also important, but lichen communities with *Cladina* spp. and some ericaceous dwarf-shrubs increase (CAVM 2002).

Tundra communities across the Arctic zone in Asia were described in a series of Russian publications that used a dominance approach to vegetation classification (GORODKOV 1958, YURTSEV et al. 1978, ALEXANDROVA 1980, MATVEEVA 1998). Phytosociological studies in those areas have been carried on recently and concerned several types of Arctic vegetation (RAZZHIVIN 1994, SINELNIKOVA 2001, KUCHEROV & DANIELS 2005). The alpine tundra vegetation in oceanic regions of Northeast Asia in Russia is poorly studied. Several publications from Kamchatka (NESHATAEV et al. 1994), the Sikhote-Alin mountains (GRISHIN et al. 1996) and Commander Islands (KRESTOV 2004) are known at present, but these few do not provide a general view of alpine tundra vegetation of the region.

In contrast, studies of alpine tundra vegetation in Japan are among the most advanced phytosociological studies (SUZUKI 1964, OHBA 1967, 1968, 1969, 1974, 1982, NAKAMURA 1986, 1987, 1994, 1997). The hierarchies of alpine vegetation in Northeast Asia were suggested in the series of publications of OHBA (1968, 1969, 1974), who introduced a worldwide-accepted class Carici rupestris-Kobresietea bellardii (OHBA 1974). Our research on northeast Asian alpine tundra vegetation in Sakhalin and Kamchatka since 1999 allowed us to extend considerably a relevé bank for this territory. This paper aims to provide a general overview of phytosociological diversity of alpine tundra communities, with special reference to their biogeographical distributional patterns.

Study area

The data were collected in oceanic regions of northeast Asia between Mt. Hakusan in Honshu(2702 m a.s.l., 36.150°N; 136.774°E, Japan) on the south, Mt. Tolbachik in Kamtchatka(3682 m a.s.l.; 55.830°N; 160.330°E, Russia) on the north. Alpine vegetation occurs on high mountains above 3000 m central Japan and above 1000 m on Kamchatka. High mountains are mainly volcanoes, including the highest peak in the northeast Asia, Kliuchevskoi (4835 m a.s.l.), 6000 years active basaltic volcano in Kamchatka; the basaltic Taisetsu Massif (2290 m) in Hokkaido; and Mts. Ontake (3063 m) and Fuji (3776 m) in Honshu. Mt. Ploskaya (3903 m) in Kamchatka is a dormant volcano with last activity estimated at 1000 years BP. Mts. Lopatina (1608 m) and Chamga (1510 m) in Sakhalin, Hidaka (2052 m) in Hokkaido, Akaishi (3193 m), Kisokomagatake (2956 m) and Hotaka (3190 m) in Honshu were formed during orogenic activity in the Paleozoic and Mesozoic eras. The substrates on which alpine vegetation occurs include, among others, sedimentary, metamorphic, peridotite, serpentinite rocks and intrusive granites.

The climate in the study area is influenced strongly by the Asian monsoon system in combination with two major baric centers, the Siberian high pressure system and the Aleutian depression. Kamchatka's interior is characterized by a continental boreal climate having low precipitation, high temperature in summer and low temperature in winter. The oceanic side of the peninsula has an oceanic boreal climate characterized by cool foggy summers and snowy winters. The warm sea currents Kuro-shio and Tsushima increase and the cold Pacific current Oya-shio decreases the mean temperature in the island arcs and adjacent mainland areas. Snow is one of the most important climatic factors for alpine vegetation. The Japanese Archipelago has a typical temperate monsoon climate that differentiates the local climates of the Pacific and Japan Sea sides. The pacific side is characterized by well expressed fens and shallow snow cover, the Japan Sea side by heavy snow cover.

Phytogeographical notions

Northeast Asia is the one of the important floristic centers of the holarctic kingdom (TAKHTAJAN 1986). The alpine flora of northeast Asia is composed of species with chiefly Euro-Siberian and Sino-Japanese distribution. The species composition of each class, however, is characterized by its own floral elements (SHIMIZU 1983, NAKAMURA 1986, 1997). The establishment of present plant communities went through considerable geological changes, particularly connected with sealevel fluctuations and the cooling period in the Quaternary. Due to the extensive changes in shoreline and wide amplitude of climatic fluctuations, as well as corresponding species migrations, the present alpine communities are composed of circumpolar, amphi-Pacific and northeast Asian elements, with a large fraction of endemic species (SHIMIZU 1983). In the oceanic sector, many species with circumpolar and / or trans-Eurasian Arctic distribution have their southern limits in the oceanic sector of northeast Asia, reaching the Japanese Archipelago (Fig. 1).

Modern species distribution patterns are explained by modern climatic conditions as well as by Pleistocene and Holocene climatic and geological changes. Before 25 million years BP, the whole study area was occupied by a flora that was close to the modern warm-temperate flora. The geological changes, as well as changes in temperature and moisture regimes in the Miocene, Pliocene and Pleistocene, led to changes in sealevel that connected and then disconnected insular areas with the continent via land bridges (GRICHUK 1984) that must be considered as important pathways for intensive floristic exchange between land massifs (TATEWAKI 1963, HULTÉN 1973). The modern pattern of temperatures and precipitation in the region was formed in the early Holocene, when general warming caused expansion of heat-dependent vegetation from Pleistocene refugia. At the same time, vegetation formed on the islands in the Pleistocene became restricted to isolated habitats, of which the alpine belts in large mountain systems became the most important modern refugia.

Plant community diversity

The preliminary prodromus of alpine tundra vegetation of the oceanic regions of northeast Asia includes 58 associations classified into 14 alliances, 8 orders and 6 classes. 23 associations are introduced here provisionally.

Carici rupestris-Kobresietea bellardii Ohba 1974

The communities of this class occur on wind-exposed slopes where shallow snow cover permits cryogenic processes in winter resulting in dry conditions in summer. Hemicryptophytes and deciduous chamaephytes are characteristic life forms. The class includes two orders (Table 1).

The order Kobresio-Dryadetalia occurs at high latitudes in the circumpolar area. The northern boundary of the Caricetalia tenuiformis is central Sakhalin, within the common range of *Carex tenuiformis, Campanula chamissonis* and *Rhodiola rosea.* Oxytropidion nigrescentis is characterized by *Pedicularis capitata, Pedicularis eryophora, Oxytropis revoluta, Oxytropis pumilio, Carex koraginensis* and *Carex fuscidula.* The alliance Bupleuro-Caricion tenuiformis occurs in central Sakhalin and Hokkaido, and is characterized by *Bupleurum triradiatum, Gentianopsis aurucilata* and *Calamagrostis sugawarae.* The alliance Oxytropidion japonicae occurs in Honshu, isolated from the Hokkaido part of its range, and is characterized by *Oxytropis japonica, Pedicularis apodochila, Artemisia glomerata* and *Agrostis flaccida.* The alliance Leontopodion hayachinensis is characterized by *Aquilegia flabellata* var. *pumila, Pinguicula vulgaris* var. *macroceras* and occurs on ultrabasic rocks.

Table 1. Regional Occurrence of wind-exposed alpine meadows

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Carici rupestris-Kobresietea bellardii Ohba 1974				
Kobresio-Dryadetalia Br.-Bl. 1948				
Oxytropidion nigrescentis Ohba 1974				
Salici arcticae-Kobresietum myosuroidis prov.	+			
Oxytropidio pumilio-Caricetum kamtschaticae prov.	+			
Caricetalia tenuiformis Ohba 1968				
Bupleuro-Caricion tenuiformis Ohba 1974				
Bupleuro triradiati-Caricetum microtrichae prov.		+	+	
Hedysaro sachalinensi-Caricetum rupestris prov.		+	+	
Salici-Oxytropidetum jezoensis Tohyama 1971		+	+	
Oxytropido megalanthae-Caricetum tenuiformis Ohba 1967		+	+	
Leontopodion hayashinensis Ohba 1974				
Leontopodio hayashinensis-Caricetum tenuiformis Ohba 1967			+	+
Saxifragetum nishidae Ohba 1974			+	+
Hypochoerido-Caricetum tenuiformis Ohba 1968			+	+
Caricetum melanocarpae Nakamura 1988			+	+
Oxytropidion japonicae Ohba 1967				
Leontopodietum shinanensis Ohba 1974				+
Saussureo-Oxytropidetum japonicae Ohba 1981				+
Euphrasio insignis-Oxytropidetum japonicae Ohba 1981				+
Leontopodietum fauriei Ohba 1967				+

Loiseleurio-Vaccinietea Eggler 1952

This class is composed of dwarf-shrub communities and occurs on well drained sites with little exposure to the wind. The species composition is represented by prostrate chamaephytes from the genera *Loiseleuria, Empetrum, Bryanthus, Arcous, Arcterica, Vaccinium* and *Diapensia.* Lichens, such as *Cetraria, Cladina, Cladonia, Stereocaulon, Thamnolia,* have a high constancy. The order Arctericetalia occurs only in the East Asia. Characteristic species of the order and alliance are *Arcterica nana, Arctous alpine* var. *japonica, Bryanthus gmelinii* and *Diapensia lapponica* ssp. *obovata.* The association Salicetum tschuktschorum occurs in boreal alpine tundra. The Arctoo-Vaccinietum uliginosi represents the summergreen dwarf-shrub communities occurring on less stable substrates, as opposed to evergreen communities of the Arcterico-Loiseleurietum procumbentis.

Table 2. Regional Occurrence of dwarf-shrub alpine tundra

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Loiseleurio-Vaccinetea Eggler 1952				
Arctericetalia Suz.-Tok. et Umezu 1964				
Arctericion Suz.-Tok. et Umezu 1964				
Salicetum tschuktschorum prov.	+			
Oxytropido pumilio-Empetretum nigri prov.	+			
Salici sphenophyllae-Vaccinietum vulcanoris prov.	+			
Betulo exilis-Vaccinietum uliginosi prov.	+			
Arctoo-Vaccinietum uliginosi Yamazaki et Nagai 1961 rassa		+		
Arctoo-Vaccinietum uliginosi Yamazaki et Nagai 1961			+	+
Arcterico-Loiseleurietum procumbentis Ohba ex Suz.-Tok.			+	+

Phyllodoco-Harrimanelletea Knapp 1954

The Phyllodoco-Harrimanelletea (Table 3) is developed under the influence of the oceanic climatic conditions and is vicarious to European Salicetea herbaceae Br.-Bl. et al. 1947. High winter precipitation in this area and deep snow cover cause the development of snow-patch communities composed of species well adapted to very short growing seasons with peak in late summer. The alliance Phyllodocion aleuticae occupies well drained habitats with late snowmelt. Characteristic species of this alliance include mainly prostrate chamaephytes such as *Phyllodoce aleutica, Phyllodoce caerulea* and *Harrimanella stelleriana* and hemicryptophytes such as *Sibbaldia procumbens* and *Primula cuneifolia.* The Phyllodocion aleuticae includes two suballiances: Salicenion polaris in Kamtchatka and Caricenion hakkodensis in Sakhalin and Japan. Faurion crista-galli indicates those sites that continue to be wet after snowmelt. Common species of this alliance are *Fauria crista-galli, Carex blepharicarpa, Gaultheria adenothrix* and *Heloniopsis orientalis.*

Table 3. Regional Occurrence of snow-patch alpine tundra

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Phyllodoco-Harrimanelletea Knapp 1954				
Harrimanelletalia Knapp 1954				
Phyllodocion aleuticae Ohba 1967				
Gentiano glaucae-Phyllodocetum caeruleae prov.		+		
Salicenion polaris prov.				
Arnico lessingii-Phyllodocetum caeruleae prov.	+			
Primulo cuneifoliae-Caricetum micropodae prov.	+			
Caricenion hakkodensis prov.				

Anaphalido-Phyllodocetum aleuticae Ohba 1975	+	+
Phyllodocetum yezoensi-aleuticae Nakamura 1988	+	+
Faurion crista-galli Suz.-Tok. 1964		
Primulo-Caricetum blepharocarpae Miyawaki et al. 1968	+	+
Primulo nipponicae-Caricetum blepharocarpae Suz.-Tok. et al. 1956	+	+

Dicentro-Stellarietea nipponicae Ohba 1968

The class Dicentro-Stellarietea nipponicae is vicarious to European Thlaspietea rotundifolii Br.-Bl. et al. 1948. It occurs on alpine bare land, including unstable sites such as patterned ground, volcanic desert, rocky slopes created by avalanches, and ultrabasic rocks. Most of the distribution area of this class lies in the Russian Far East and eastern Siberia; some communities occur also in boreal eastern North America. The class includes two orders (Table 4). The Oxygraphiso glacialis-Minuartietalia arcticae occurs at higher latitudes, where it replaces the order Minuartietalia vernae japonicae characteristic to Honshu, Hokkaido and Sakhalin. The alliance Saxifrago funstonii-Stellarion eschoscholtzianae in Kamtchatka occupies elevations from 600 to 1520 m. and is characterized by *Lagotis glauca, Potentilla vulcanicola, Poa malacantha, Poa arctica,* etc. This alliance occurs on volcanic barrens and wet unstable sites around snow patches.

The order Minuartietalia vernae japonicae occurs in Sakhalin and Hokkaido and is characterized by *Festuca ovina* var. *alpina, Potentilla matsumurae, Minuartia verna* var. *japonica, Agrostis flaccida.* It includes four alliances. The Violo-Polygonion ajanensis that occurs on volcanic barrens and limestone is characterized by *Polygonum ajanensis, Saxjfraga sachalinensis, Bupleurum triradiatum, Campanula uyemurae* and *Poa neosachalinensis*. The Caricion flavocuspis occurs on mesic fine volcanic materials at elevation 1330 to 2230 m. on Hokkaido and in Tohoku (northeastern Honshu). The Stellarion nipponicae occurs in central Honshu, from 2410 to 3260 m elevation, on dry unstable volcanic barrens and is characterized by *Stellaria nipponica, Minuartia hondoensis, Cerastium schizopetarum, Polygonum weyrichii* var. *alpinum, Carex stenantha,* etc. The Drabo-Arenarion katoane is characteristic of ultrabasic rocks in Hokkaido and Honshu. *Draba japonica* and *Arenaria katoana* are characteristic species.

Table 4. Regional Occurrence of alpine bareland plant communities

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Dicentro-Stellarietea nipponicae Ohba 1968				
Oxygrapho glacialis-Minuartietalia arcticae prov.				
Saxifrago funstonii-Stellarion eschscholtzianae prov.				
Junco biglimi-Lagotisetum glaucae prov.	+			
Ermannio-Papaveretum microcarpae prov.	+			
Minuartio microcarpae-Artemisietum glomeratae prov.	+			
Saxifragetum merckii prov.	+			
Minuartietalia vernae-japonicae Ohba 1968				
Violo-Polygonion ajanensis Ohba 1969				
Oxyrio-Taraxacetum tatewakii prov.		+		
Scorsonero radians-Miyakeetum integrifoliae prov.		+		
Bupleuro ajanensis-Saussuretum kitamurae prov.		+		
Thlaspi cochleariiformis-Artemisietum koidzumii prov.		+		
Drabo ussuriensis-Minuartietum vernae prov.		+		
Potentillo miyabei-Arenerietum merckioidis Nakamura 1988			+	
Papaveretum fauriei Ohba 1969			+	
Thlaspi-Polygonetum ajanensis Ohba 1969			+	

Caricion flavocuspis prov.				
Carici-Saxifragetum merckii Ohba 1969			+	+
Arenerietum merckioidis chokaiensis Ohba 1969			+	+
Reg. ass. Dicentro-Violetum crassae Ohba 1969			+	+
Stellario-Polygonetum ajanensis Ohba 1969			+	+
Drabo-Arenarion katoanae Ohba 1968				
Cerastio-Minuartietum vernae japonicae Ohba 1968			+	+
Arenarietum lanceolatae Ohba 1968			+	+
Saussuretum chionophyllae Ohba 1968			+	+
Sanguisorbo-Minuartietum vernae japonicae Ohba 1968			+	+
Leontopodietum fauriei angustifolii Ohba 1968			+	+
Stellarion nipponicae Ohba 1969				
Dicentro-Violetum crassae Ohba 1969				+
Melandryo-Cerastietum schizopetali Ohba 1969				+
Sedo rosei-Saxifragetum bronchialis funstonii Nakamura 1986				+
Arabido-Polygonetum weirichii Ohba 1969				+
Stellario nipponicae-Caricetum stenanthae prov.				+

Montio-Cardaminetea Br.-Bl. et Tüxen 1943

This class occurs widely over the Northern Hemisphrere in montane to alpine belts. It combines the various plant communities dependent on water from permanent springs, occurring on wet, oligotrophic sites. Sagino sagioidis-Stellarietalia umbellatae has a wide distribution area in alpine belts from central Eurasia to western North America. Epilobio alpini-Saxifragion porsildianae is characterized by *Saxifraga porsildiana, Saxifraga calycina, Epilobium alpinum.* Characteristic genera of this class are herbs *Epilobium, Saxifgara, Chrysosplenium, Cardamine, Stellaria* and *Ranunculus* and bryophytes *Pohlia, Bryum, Hygrogypnum.*

Table 5. Regional Occurrence of Spring-water plant communities

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Montio-Cardaminetea Br.-Bl. et Tx. 1943				
Sagino-saginoidis-Stellarietalia umbellatae prov.				
Epilobio alpini-Saxifragion porsildianae prov.				
Stellario calycanthae-Epilobietum hornemannii prov.	+			
Cardamino umbellatae-Ranunculetum altaici prov.	+			
Minuartio microcarpae-Artemisietum glomeratae prov.	+			
Ranunculo pygmaei-Cardaminetum sachalinensis prov.	+	+		

Salicetea arcticae prov.

The class Salicetea arcticae occurs at high latitudes in the Arctic tundra zone, occupying mesic to humid habitats and covering rather extensive areas. The plant communities are composed of prostrate chamephytes and dominated by dwarf-shrub species of *Salix*. The order Salicetalia reticulate-chamissonis is characteristic to the oceanic sectors of the Russian Far East and western Alaska. The Salicetum reticulatae-chamissonis was first described in Kamtchakta. *Salix reticulata* and *Salix arctica* usually dominate the communities, in combination with *Salix chamissonis, Salix sphenophylla* and *Salix ovalifolia.*

Table 6. Regional Occurrence of dwarf willow alpine tundra

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
<u>Salicetea arcticae prov.</u>				
Salicetalia reticulato-chamissonis prov.				
Salicion reticulato-chamissonis prov.				
Salicetum reticulato-chamissonis prov.	+			

Phytosociological diversity of Alpine Vegetation in Northeast Asia

Phytosociological diversity of the alpine vegetation in the oceanic sector of northeast Asia is much higher than in the continental sectors. The oceanic climatic conditions provide very deep snow cover and better protection of the ground from winter freezing, in northern areas very short growing seasons that reduce competition from other potential dominants and comfortable moisture conditions. During the Pleistocene Maximum ice sheets did not cover northeast Asia, and an arid climate was established on extensive areas of the Asian mainland (Grichuk 1984). The oceanic sector of northeast Asia in the Pleistocene was likely a very important refugium supporting humidity-dependent vegetation. The sea regression caused the appearance of land bridges between islands and between them and the mainland. Therefore north-south oriented long island arcs could serve as corridors for vegetation migration, especially for drought-tolerant species associated with continental tundra communities.

From the distributional pattern of six classes, the most important boundary line that divides alpine vegetation lies between Sakhalin and Kamchatka. Most southern and northern alliances and orders are geographically isolated in Kamchatka, with greater influence of Beringian floristic centers and Sakhalin-Hokkaido-Honshu influenced mainly by the Sino-Japanese flora. Distribution of the Bupleuro-Caricion tenuiformis of the Carici rupestris-Kobresietea bellardii is restricted to Sakhalin and Hokkaido. The Violo-Polygonion ajanensis occurs on Sakhalin, Hokkaido and Honshu. In contrast to southern regions, Kamchatka is characterized by species with circumboreal and circumpolar distribution, as illustrated by the geographical ranges of shrubby *Salix* and *Betula* species.

Honshu represents the southernmost boundary of alpine vegetation, which in this area does not form an alpine belt but occurs on azonal habitats such as volcanic barrens, rock outcrops and other sites with specific topographic and wind conditions that prevent occurrence of the zonal vegetation. The number of species in vegetation units in southernmost tundra communities however, remains comparable to their northern analogs. The communities of the Carici rupestris-Kobresietea bellardii contain from 15 to 25 species, Loiseleurio-Vaccinietea from 10 to 25 species, and Dicentro-Stellarietea nipponicae from 9 to 14 species.

On the second highest peak of Honshu, Mt. Kitadake (3192m), there were found several species whose main range lies at high latitudes in Arctic, such as *Saxifraga cernua, S. bronchialis* ssp. *funstonii, Arenaria macrocarpa, Potentilla nivea, Artemisia glomerata, Luzula arcuata* ssp. *unalaschensis, Ptilagrostis mongholica* and *Poa malacantha*. Not only northern elements but also endemic species such as *Saussurea triptera* var. *minor* and *Seseli libanotis* ssp. *japonica* f. *alpicola,* that were differentiated from their low-altitude parents likely in Pleistocene, contribute to the alpine tundra diversity (NAKAMURA 1997). Limestone and ultrabasic rocks on high mountains are among the best low-altitude habitats for alpine vegetation in southern regions.

The alpine belts in modern time generally are being affected by devastating human activity or grazing by livestock. The moderate influence on the alpine belt of tourist activities does not bring fatal destruction to the plant communities. Up to now no evidence of decline of alpine vegetation because of global warming and air pollution has been provided. However, severe climatic influences such as great temperature amplitudes at different time scales, winds, rainfalls, soil erosions and great volcanic activity makes the alpine substrates very dynamic. Appearance of new substrates under the different climatic conditions, a great variety of primary succession paths and the co-existence of species with different geographical ranges leads to diversification of the biota at the species and community levels and to development of plant adaptations to different conditions that makes alpine tundra communities one of the most complicated subjects for study.

Acknowledgements

This study was supported by Japanese-Russian exchange program (2006-2007), Russian foundation for basic research (06-04-91451, 07-04-00654) and Far Eastern Branch of Russian Academy of Sciences (06-III-A-06-147).

Literature

ALEXANDROVA, V.D. (1980): *The Arctic and Antarctic: Their Division into Geobotanical Areas.* – 247 p., – Cambridge University Press, Cambridge.

CAVM Team. (2003): *Circumpolar Arctic Vegetation Map. (1:7,500,000 scale).* – Map No. 1 U.S. Fish and Wildlife Service, Anchorage, AK.

GORODKOV, B.N. (1958): The vegetation and soils of the Wrangell Island. – In: Tikhomirov, B.A. (ed.), *The vegetation of Far North of the USSR and its management*, – pp. 5-58. – Izdatel'stvo Akademii Nauk, Moscow (in Russian).

GRICHUK, V.P. (1984): Late Pleistocene Vegetation History. In: Anonymous. *Late Quaternary environments of Soviet Union*, – pp. 155-178. – Univ. Minnesota Press, Minneapolis.

GRISHIN, S.Y., KRESTOV, P.V. & OKITSU, S. (1996): The subalpine vegetation of Mt. Vysokaya, central Sikhote-Alin. – *Vegetatio* 127: 155–172.

HULTÉN, E. (1968): Flora of Alaska and Neighboring Territories. – 1008 p., California.

HULTÉN, E. (1973): Supplement to flora of Alaska and neighboring territories. A study in the flora of Alaska and the transberingian connection. – *Botaniska notiser* 126: 459-512.

KOLESNIKOV, B.P. (1961): Vegetation. – In: Richter, G.D. (ed.), *Far East. Physiogeography* – pp. 183-245 – Izdatel'stvo Akademii Nauk SSSR, Moscow (in Russian).

KOZHEVNIKOV Y.P. (1996): *Vegetation cover of northern Asia in historical perspective* – 400 p. – Mir i Semya, St. Petersburg. (in Russian).

KRESTOV, P.V. (2004): Plant cover of Commander Islands. – *Botanicheskiy Zhurnal* 89(11): 1740-1762. (In Russian).

KUCHEROV, I, & DANIËLS, F.J.A. (2005): Vegetation of the Classes Carici-Kobresietea and Cleistogenetea squarrosae in Central Chukotka. – *Phytocoenologia* 35 (4): 1019-1066.

MATVEYEVA, N.V. (1998): Zonation in Plant Cover of the Arctic. – *Russian Academy of Sciences, Proceedings of the Komarov Botanical Institute*, No. 21. St. Petersburg, RU. (In Russian.)

NAKAMURA, Y. (1986): Pflanzensoziologische Untersuchung der alpinen und subalpinen Vegetation der westlichen Gebirge von Honshu (Chubu, Kii und Shikoku), -Teil 1. Vegetationseinheiten und ihre systematische Betrachtung. *Bull. Inst. Environ. Sci. & Tech. Yokohama Nat. Univ.* 15: 151-206.

NAKAMURA, Y. (1987): Pflanzensoziologische Untersuchung der alpinen und subalpinen Vegetation der westlichen Gebirge von Honshu (Chubu, Kii und Shikoku), -Teil 2. Areale der Pflanzensippen und der Pflanzengesellschaften. *Bull. Inst. Environ. Sci. & Tech. Yokohama Nat. Univ.* 16: 83-107.

NAKAMURA, Y. (1994): A comparative study of the alpine vegetation of Eastern North America and Japan. (Edits: Miyawaki, A., Iwatsuki, K. & Grandtner, MM.; Vegetation in Eastern North America). 335-347. University of Tokyo press, Tokyo.

NAKAMURA, Y. (1997): A phytogeographical study of Kobresio-Oxytropidetum nigrescens japonicae. – *Jap. J. Ecol.* 47:249-260.

NESHATAEV, Y.N., NESHATAEVA, V.Y. & NAUMENKO, A.T. (EDS.) (1994): *Vegetation of Kronotskiy State Reserve*, – Komarov Botanical Institute Press, St-Peterburg (in Russian).

OHBA, T. (1967): Alpine belt of Japan. (Edt. Miyawaki, A.: Vegetation of Japan). 373-420. Gakken press, Tokyo.

OHBA, T. (1968): Über die Serpentin Pflanzengesellschaften der alpinenStufe Japans. *Bull. Kanagawa Pref. Museum* 1: 37-64.

OHBA, T. (1969): Eine pflanzensoziologische Gliederung über die Wüstenpflanzengesellschaften auf alpinen Stufe Japans. *Bull. Kanagawa Pref. Museum* 2: 23-70.

OHBA, T. (1974): Vergleichende Studien über die alpine Vegetation Japans. *Phytocoenologia* 1: 339-401.

OHBA, T. (1982): Vegetation of Japan. (Edts. Higuchi, Y., Fukuoka, M. & Yasojima, Y.: The Body of Civil Engineering 3). 69-210. Shokokusha press, Tokyo.

RAZZHIVIN, V.Y. (1994): Snowbed vegetation of far northeastern Asia. – *J. Veg. Sc.* 5: 829-842.

SHIMIZU, T (1982): The new Alpine Flora of Japan in color, vol. 1. – 331p., Ohsaka.

SHIMIZU, T (1983): The new Alpine Flora of Japan in color, vol. 2. -395p., Ohsaka.

SINELNIKOVA, N.V. (2001): Classification of shrubby willow communities in the central Chukotka (Anadyr, Amguema and Omolon river basins). – In: A.N. Kupriyanov (ed.) Botanical researches in Siberia and Kazakhstan, pp. 50-69, – Altai Univ. Press, Barnaul. (In Russian).
SUZUKI, T. (1964): Übersicht auf die alpinen und subalpinen Pflanyengesellschaften im inneren KurobeßGebiet. The Synthetic Science Research Organization of the Toyama Univ. 1-25. Toyama.
TAKHTAJAN, A.L. (1986): *Floristic regions of the world*, 280 p. – University of California Press, Berkeley.
TATEWAKI, M. (1963): Hultenia. – *J. Fac. Agr. Hokkaido Univ.* 53: 133-199.
TSUKADA, M. (1984): A vegetation map in the Japanese Archipelago approximately 20,000 Years B.P. *Jap. J. Ecol.* 34: 203-208.
YURTSEV, B.A. (1978): The botanical-geographic characterization of Southern Chukotka. – *Komarovskiye chteniya* 26: 3-62 (in Russian).

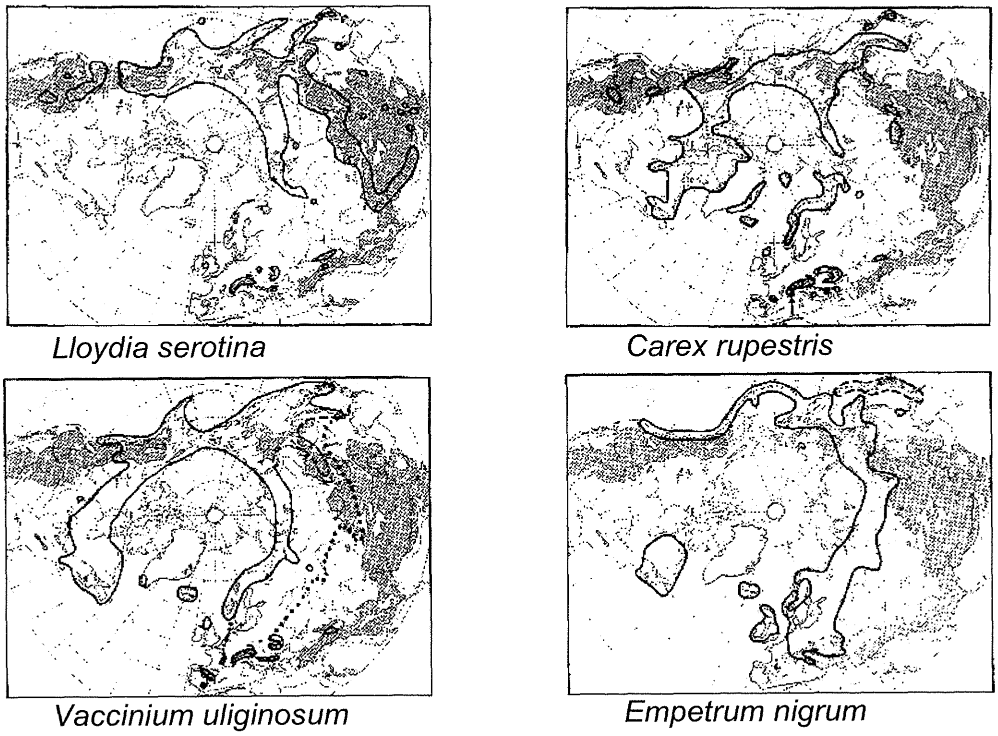


Fig. 1: Distribution map of Alpine plants (Hultén 1968)

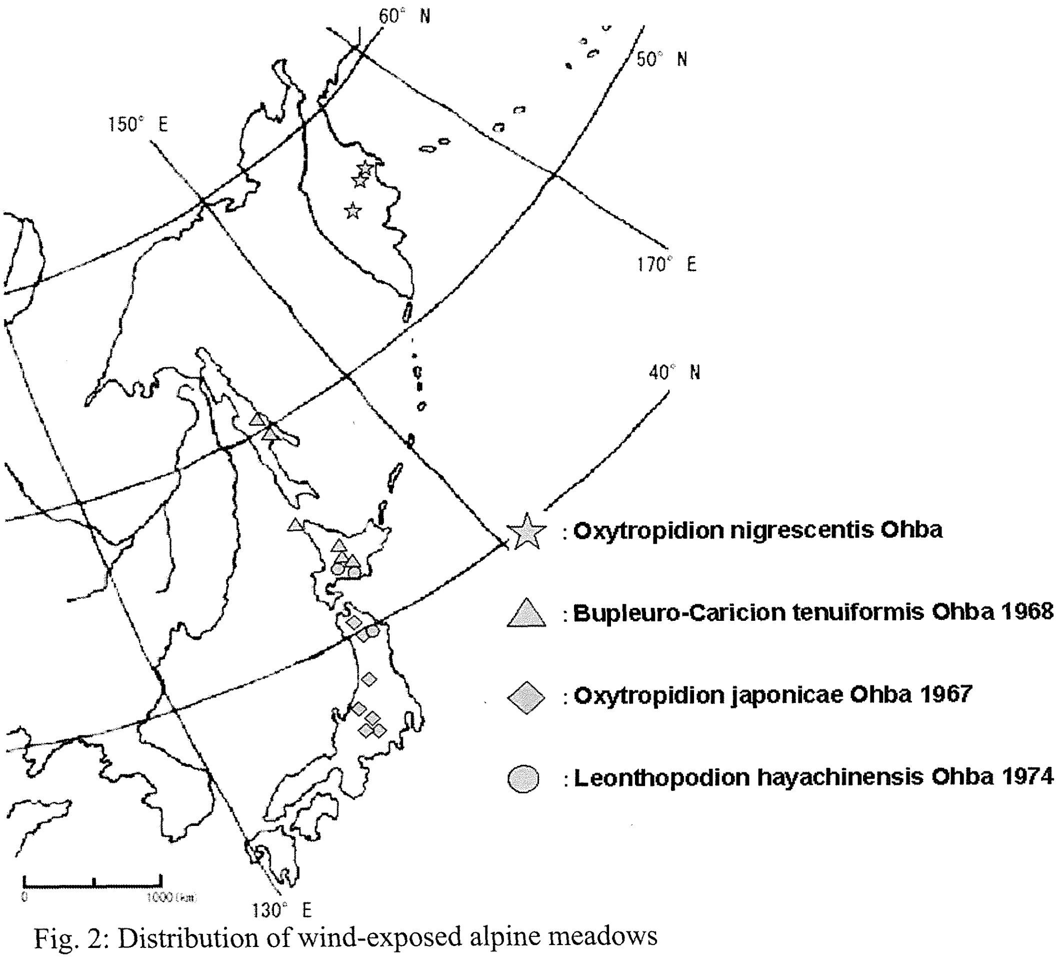


Fig. 2: Distribution of wind-exposed alpine meadows

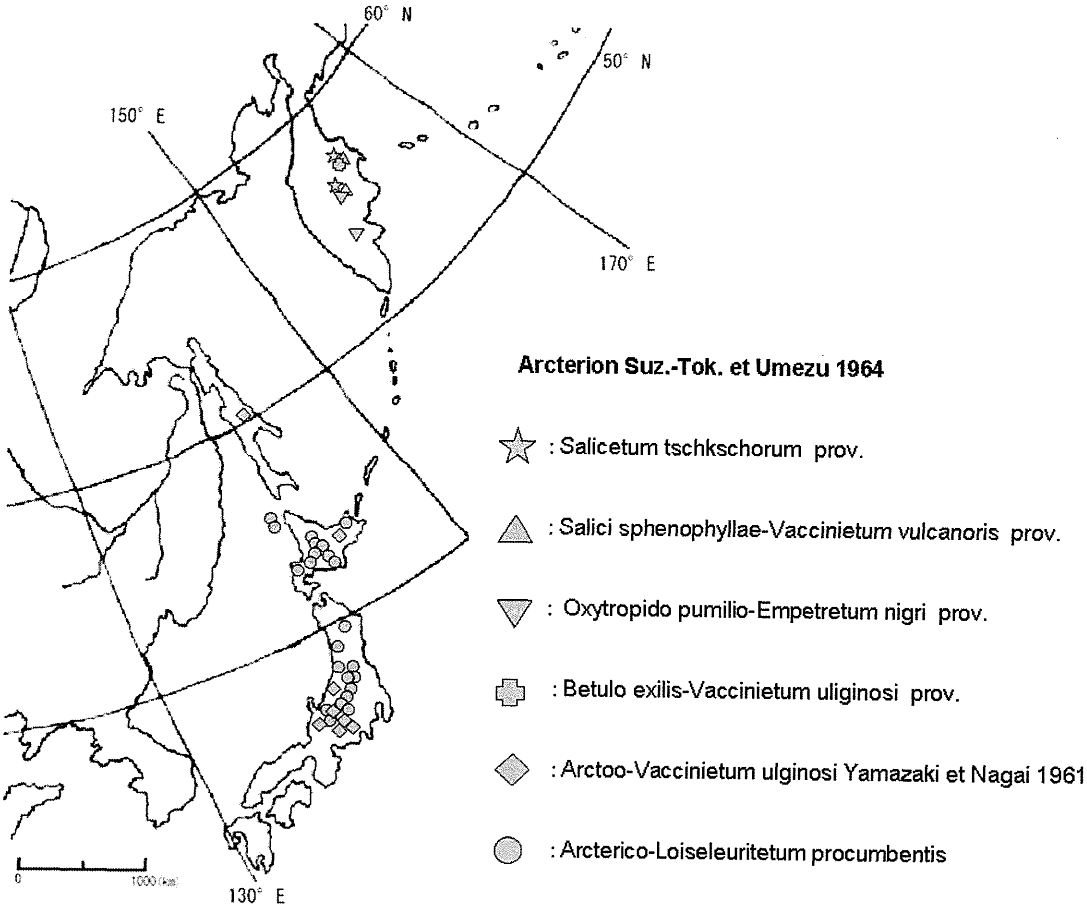


Fig. 3: Distribution of dwarf-shrub alpine tundra

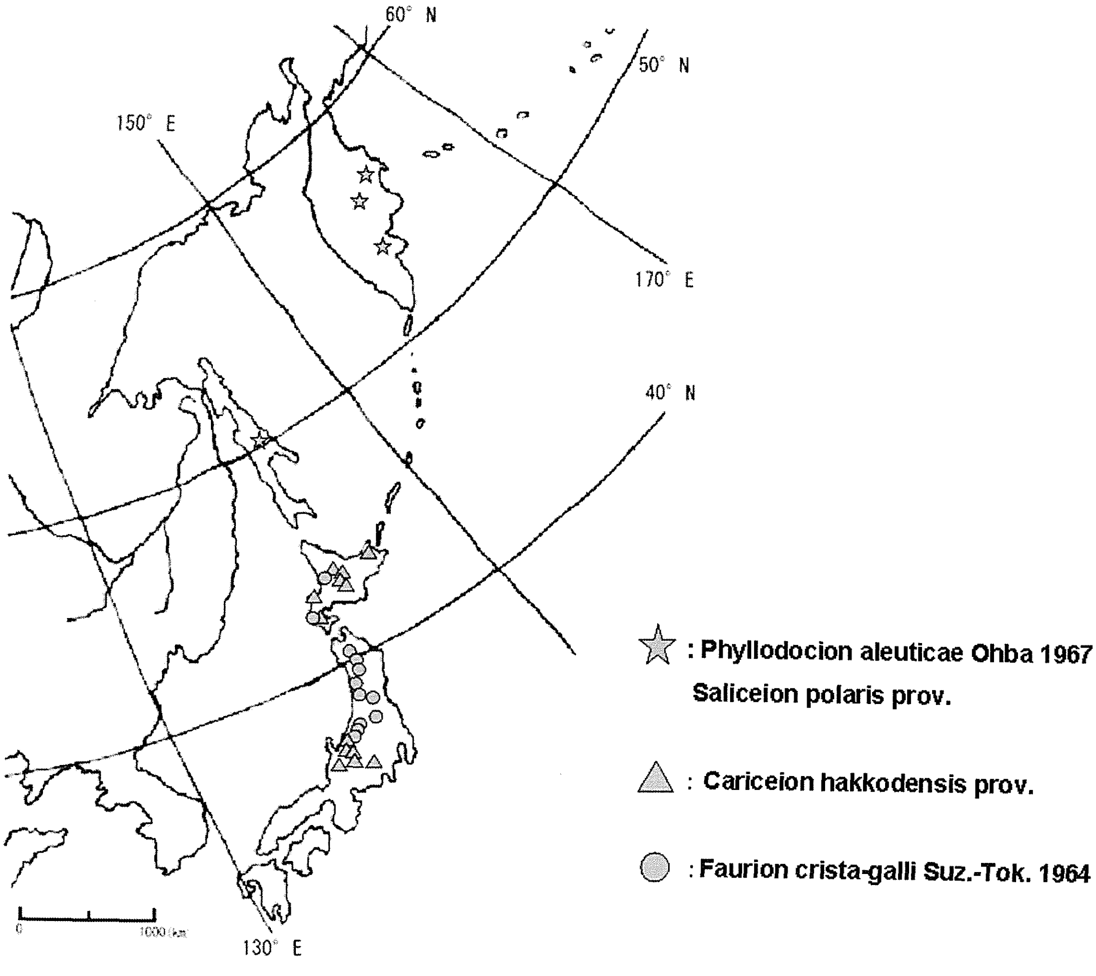


Fig. 4: Distribution of snow-patch alpine tundra

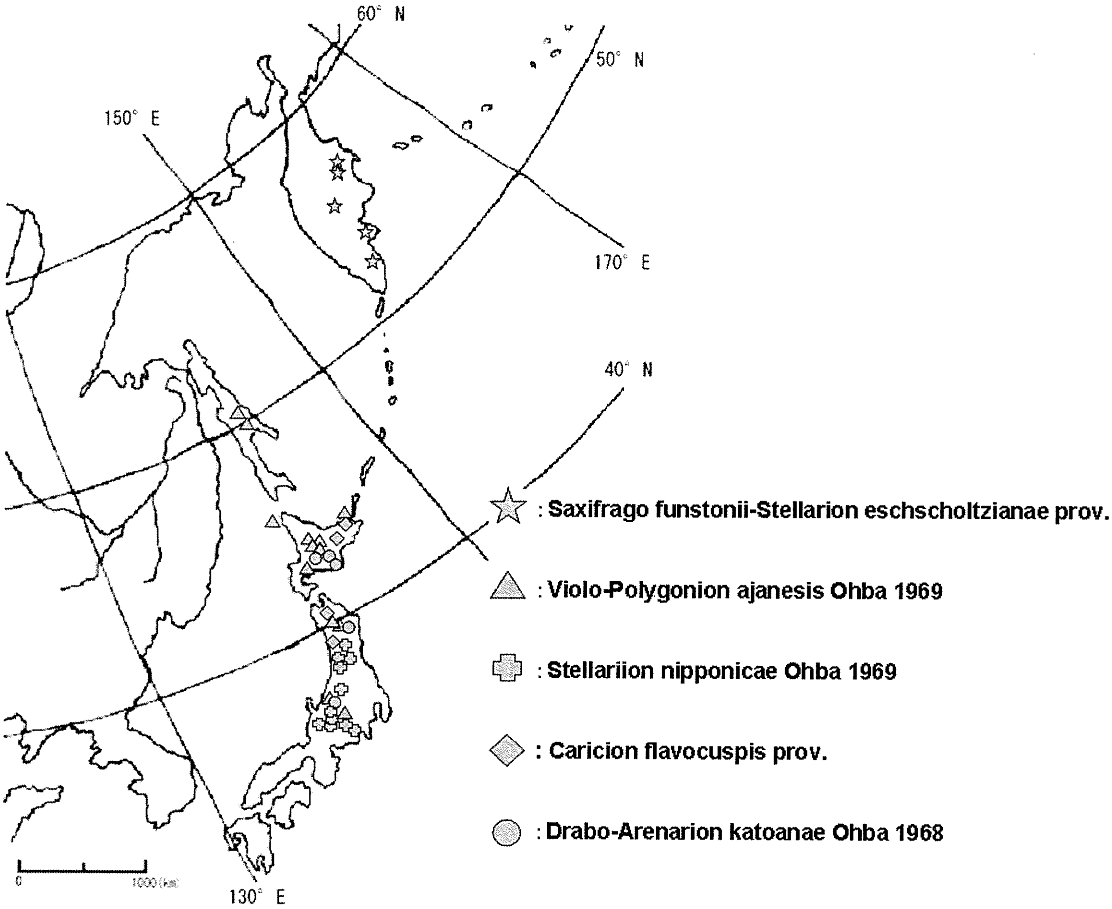


Fig. 5: Distribution of alpine bare land plant communities

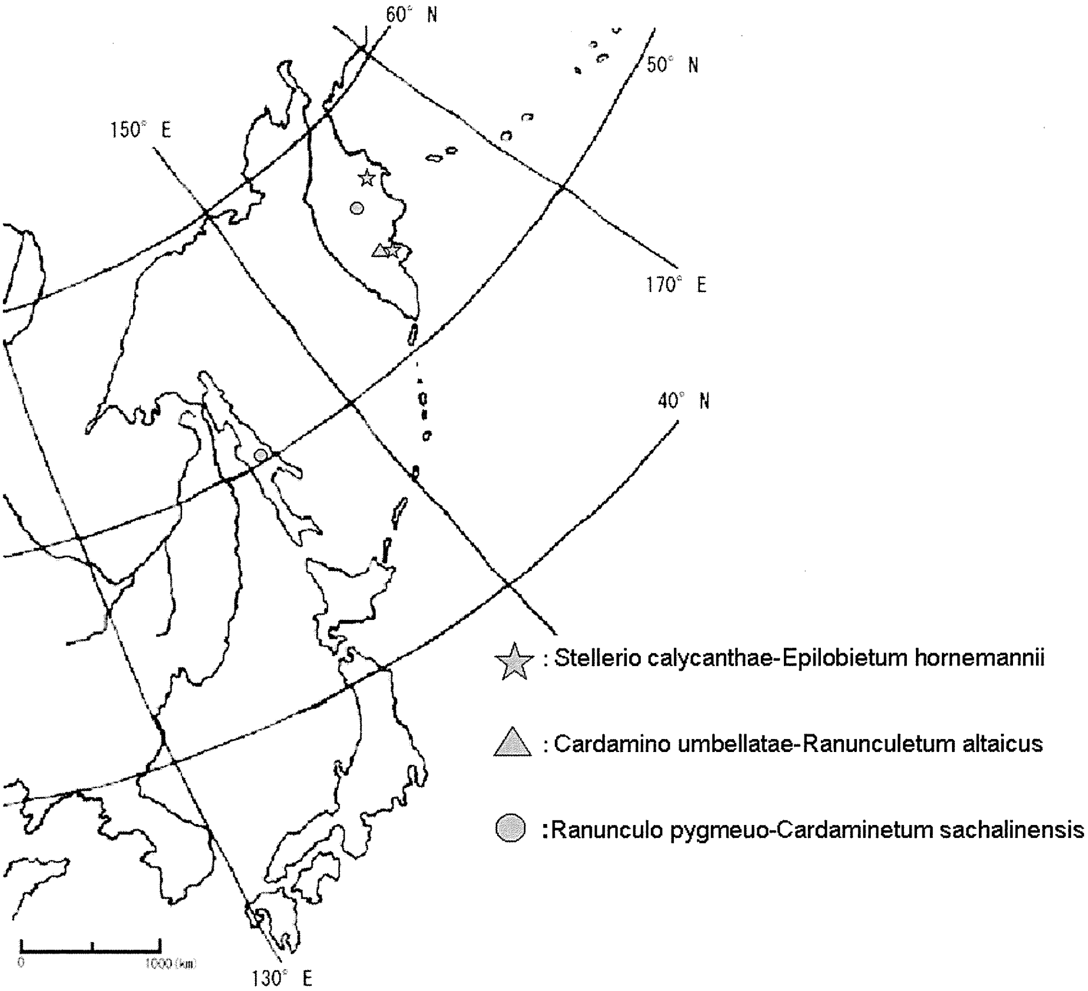


Fig. 6: Distribution of alpine spring-water plant communities

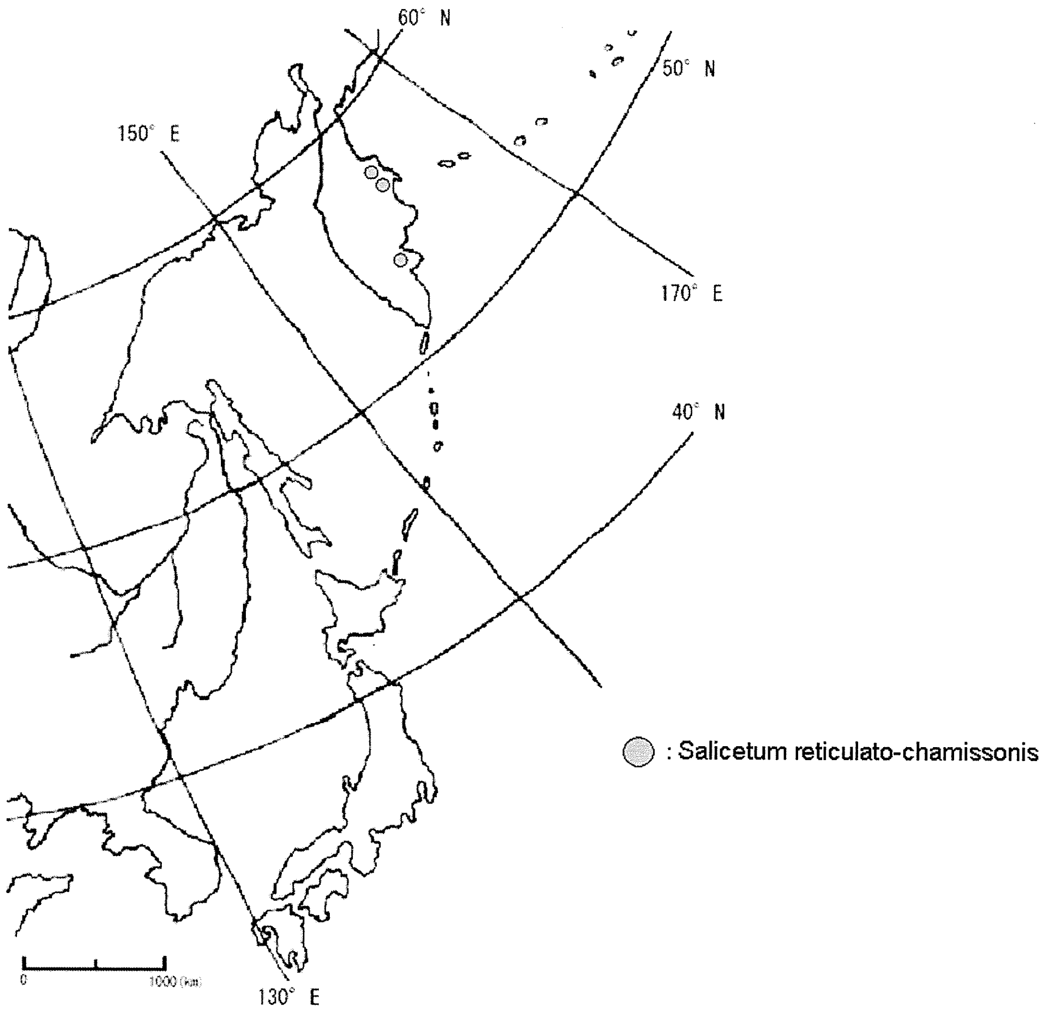


Fig. 7: Distribution of dwarf willow alpine tundra

Alpine Tundra in China & Tibet, 2006

Cheilanthes argentea–Selaginella tamariscina community

Running Nr.	1	2	3
Releve Nr.	T–3	T–4	T–5
Latitude	29	29	29
	31	31	31
	395	395	395
Longitude	90	90	90
	56	56	56
	168	168	168
Date	9	9	9
	21	21	21
Exposition	SE	SE	SE
Slope	80	85	80
Elevation	3652	3672	3662
Height of vegetation (cm)	5	6	8
Coverage of vegetation (%)	30	30	20
Coverage of Moss layer (%)	–	40	40
Quadrat size	03X1	2X2	2X2
Species Nr.	5	3	4
Differential species of community:			
Cheilanthes(Aleuritopteris) argentea	1・2	1・2	・
Selaginella cf. tamariscina(nummularifolia)	3・4	3・4	2・3
Huperzia selago	+	・	+・2
Sedum ewersii	+	1・2	1・2
Tripogon bromoides	+・2	・	・
Cotoneaster microphyllus	・	・	1・1

Alpine Tundra in China & Tibet, 2006

a: Elymo nutantis–Kobresietum humilis
  i: Typicum
  ii: astragalietosum qingnqnicus

b: Leontopodio nanumi–Kobresietum pygmaeae

c: Rheumo globulosi–Kobresietum pygmaeae

			a			b			c		
		i		ii							
Running Nr.	4	5	1	2	3	7	6	8	9	10	11
Releve Nr.	Q–7	Q–11	Q–4	Q–5	Q–6	Q–14	Q–12	T–8	T–9	T–11	T–15
Latitude	36	36	37	36	36	36	36	29	29	29	29
	55	25	0	58	58	22	26	3	3	3	3
	532	452	172	87	105	422	311	545	321	534	514
Longitude	99	101	100	99	99	101	101	88	88	88	88
	35	93	48	35	35	22	5	0	0	0	0
	167	441	550	581	590	371	201	96	104	116	149
Date	9	9	9	9	9	9	9	9	9	9	9
	16	17	16	16	16	17	17	22	22	22	22
Exposition	L	L	NW	L	L	W	E	NW	NW	NW	NW
Slope	–	–	15	–	–	20	15	5	10		5
Elevation	3208	3461	3200	3213	3207	3742	3514	4487	4520	4533	4668
Height of vegetation (cm)	5	5	50	20	15	8	10	5	5	5	5
Coverage of vegetation (%)	90	60	100	80	80	70	80	60	40	50	70
Coverage of Moss layer (%)	–	–	–	–	–	10	–	–	–	–	–
Quadrat size	2X2	3X3	5X5	5X5	3X3	1x1	5X5	3X3	2X2	2X2	2X2
Species Nr.	16	13	38	21	20	20	27	23	22	24	22
Characteristic & differential species of associations:											
Elymus nutans	1·1	1·1	3·4	2·2	2·2	·	1·1	·	·	·	·
Potentilla bifurca	+	1·1	+·2	+	·	·	·	·	·	·	·
Potentilla saundersiana	1·1	+·2	1·2	·	·	·	1·1	·	·	·	·
Koeleria cristata	·	·	+·2	2·2	1·1	·	·	·	·	·	·
Melilotoides archiducis–nicolai	·	·	1·1	+·2	2·3	·	·	·	·	·	·
Poa sinoglauca	·	·	·	+	+	·	·	·	·	·	·
Heteropappus altaicus	·	·	·	+	+	·	·	·	·	·	·
Astragalus qingnanicus	·	·	·	+·2	1·2	·	·	·	·	·	·
Carex moorcroftii	·	·	·	1·1	+·2	3·4	·	·	·	·	·
Leontopodium nanum	·	·	·	·	·	2·3	2·3	·	·	·	·
Gentiana lawrencei var. farreri	·	·	·	·	·	1·1	+·2	·	·	·	·
Saussurea katochaete	·	·	·	·	·	+	1·1	·	·	·	·
Gentiana pseudosquarrosa	·	·	·	·	·	·	·	1·1	1·1	1·1	1·1
Carex oxyleuca	·	·	·	·	·	·	·	1·1	2·2	1·1	2·3
Rheum globulosum	·	·	·	·	·	·	·	1·1	+·2	+	+
Silene caespitella	·	·	·	·	·	·	·	+·2	+·2	+·2	+
Androsace tapete	·	·	·	·	·	·	·	1·1	3·3	2·2	·
Heteropappus gouldii	·	·	·	·	·	·	·	·	+·2	1·1	+
Incarvillea younghusbandii	·	·	·	·	·	·	·	·	1·1	+	1·2
Potentilla polyschista	·	·	·	·	·	·	·	·	+	+·2	+
Viola nudicaulis	·	·	·	·	·	·	·	+·2	+·2	·	·
Youngia simulatrix	·	·	·	·	·	·	·	+	+·2	·	·
Arenaria capillaris var. glandulosa	·	·	·	·	·	·	·	·	1·2	1·2	·
Roegneria breviglumis	·	·	·	·	·	·	·	·	1·1	1·1	·
Potentilla parvifolia	·	·	·	·	·	·	·	·	·	+	+·2
Kobresia pygmaea	1·2	·	·	4·5	1·2	2·3	3·4	3·3	3·3	3·3	4·4
Kobresia humilis	4·5	3·4	2·2	2·3	3·4	·	3·3	1·1	1·2	1·2	·
Lancea tibetica	2·3	·	+	+	2·2	·	1·2	1·2	1·1	+	1·1
Festuca ovina	1·2	2·2	3·4	2·2	2·3	1·2	2·2	·	·	·	·
Gentiana straminea	·	·	+·2	·	1·1	·	+	+·2	+	+	+
Stipa purpurea	·	+	1·2	2·2	1·1	·	·	·	+·2	·	1·2
Dracocephalum heterophyllum	·	+·2	(+)	+	·	·	·	+	·	+	·
Veronica ciliata ssp. cephaloides	·	·	+·2	·	·	·	·	1·1	1·1	1·1	+·2
Stellaria chamaejasme	·	+	1·1	+	·	·	1·1	·	·	·	·
Stipa aliena	·	·	+·2	·	1·1	·	+	·	·	·	·
Taraxacum sp.	+	·	+	+	·	·	·	·	·	·	·
Anaphalis lactea	·	·	2·2	·	·	·	1·2	·	·	·	·
Sedum sp.	·	·	·	·	·	·	·	+	+	·	+
Saussurea sp. 裏白	·	·	·	·	·	·	·	·	+	+	+
Halerpestes tricuspis	+	·	+	·	·	·	·	·	·	·	·
Potentilla anserina	1·2	·	+	·	·	·	·	·	·	·	·
Thalictrum alpinum	2·2	·	+	·	·	·	·	·	·	·	·
Taraxacum mongolicum	+	·	·	·	+·2	·	·	·	·	·	·
Potentilla multifida	·	·	1·1	·	+	·	·	·	·	·	·
Bupleurum smithii var. parvifolium	·	·	3·4	·	·	·	+·2	·	·	·	·
Oxytropis kansurensis	·	·	1·2	·	·	·	1·1	·	·	·	·

Comastoma pulmonarium	・	・	1・2	・	・	・	+・2	・	・	・	・
Bupleurum sp.−1 ﾋｹﾞｼﾊﾞﾓﾄﾞｷ	・	・	・	・	・	・	・	+	・	+	・
Poa litwinowiana	・	・	・	・	・	・	・	+	・	+	・
Swertia hispidcalyx var. subglabra	・	・	・	・	・	・	・	・	・	+	+
Arenaria bryophylla (Chousei)	・	・	・	・	・	・	・	・	・	・	・
Primula nutans	2・3	・	・	・	・	・	・	・	・	・	・
Ranunculus membranaceus var. pubescens	1・1	・	・	・	・	・	・	・	・	・	・
Gentiana grumii	+・2	・	・	・	・	・	・	・	・	・	・
Glaux maritima	+	・	・	・	・	・	・	・	・	・	・
Sibbardia tetrandra	・	1・1	・	・	・	・	・	・	・	・	・
Oxytropis sp.	・	1・1	・	・	・	・	・	・	・	・	・
Roegneria hirsuta var. variabilis	・	+	・	・	・	・	・	・	・	・	・
Artemisia algida	・	+	・	・	・	・	・	・	・	・	・
Achnantherum inebrians	・	(+)	・	・	・	・	・	・	・	・	・
Gentianopsis paludosa	・	・	2・2	・	・	・	・	・	・	・	・
Oxytropis ochorocephala	・	・	2・2	・	・	・	・	・	・	・	・
Astragalus sp.	・	・	2・2	・	・	・	・	・	・	・	・
Pedicularis kansuensis	・	・	1・2	・	・	・	・	・	・	・	・
Astragalus polycladus	・	・	1・1	・	・	・	・	・	・	・	・
Galium verum	・	・	1・1	・	・	・	・	・	・	・	・
Oxytropis glabra	・	・	1・1	・	・	・	・	・	・	・	・
Kobresia capillifolia	・	・	(+・2)	・	・	・	・	・	・	・	・
Kobresia royleana	・	・	+・2	・	・	・	・	・	・	・	・
Ajania tenuiflora	・	・	+・2	・	・	・	・	・	・	・	・
Carex scabrirostris	・	・	+・2	・	・	・	・	・	・	・	・
Morina chinensis	・	・	+	・	・	・	・	・	・	・	・
Pedicularis verticillata	・	・	+	・	・	・	・	・	・	・	・
Ptilagrostis dichotoma	・	・	+	・	・	・	・	・	・	・	・
Silene tenuis	・	・	(+)	・	・	・	・	・	・	・	・
Stipa krylovii	・	・	・	+・2	・	・	・	・	・	・	・
Carex sp.	・	・	・	+・2	・	・	・	・	・	・	・
Aconitum gymnandrum	・	・	・	+	・	・	・	・	・	・	・
Artemisia phaeolepis	・	・	・	+	・	・	・	・	・	・	・
Leontopodium leontopodioides	・	・	・	+	・	・	・	・	・	・	・
Carex sp. Small	・	・	・	・	+・2	・	・	・	・	・	・
Androsace erecta	・	・	・	・	+	・	・	・	・	・	・
Polygonum siberica	・	・	・	・	+	・	・	・	・	・	・
Festuca rubra	・	・	・	・	+	・	・	・	・	・	・
Caltha scaposa	・	・	・	・	・	2・2	・	・	・	・	・
Blysmus sinocompressus	・	・	・	・	・	1・2	・	・	・	・	・
Cladonia coccifera group	・	・	・	・	・	1・2	・	・	・	・	・
Comastoma falcatum	・	・	・	・	・	1・2	・	・	・	・	・
Racomitrium canescens?	・	・	・	・	・	1・2	・	・	・	・	・
Cheiranthus roseus	・	・	・	・	・	+	・	・	・	・	・
Coluria longifolia	・	・	・	・	・	+	・	・	・	・	・
Dicranum sp.	・	・	・	・	・	+	・	・	・	・	・
Draba lanceolata var. leiocarpa	・	・	・	・	・	+	・	・	・	・	・
Parnassia trinervis	・	・	・	・	・	+	・	・	・	・	・
Lloydia serotina ?	・	・	・	・	・	+	・	・	・	・	・
Stellaria sp.	・	・	・	・	・	+	・	・	・	・	・
Viola sp.	・	・	・	・	・	+	・	・	・	・	・
Astragalus sp.	・	・	・	・	・	(+)	・	・	・	・	・
Bistorta vivipar	・	・	・	・	・	・	2・2	・	・	・	・
Oxytropis sp.	・	・	・	・	・	・	2・2	・	・	・	・
Carex atrafusca	・	・	・	・	・	・	1・1	・	・	・	・
Saussurea eupygmaea	・	・	・	・	・	・	1・2	・	・	・	・
Primula sp.	・	・	・	・	・	・	1・1	・	・	・	・
Taraxacum sp.	・	・	・	・	・	・	+・2	・	・	・	・
Gentiana spathulifolia	・	・	・	・	・	・	+・2	・	・	・	・
Saussurea superba	・	・	・	・	・	・	+	・	・	・	・
Euphorbia altotobetica	・	・	・	・	・	・	+	・	・	・	・
Pedicularis odera	・	・	・	・	・	・	+	・	・	・	・
Potentilla fruticosa	・	・	・	・	・	・	+	・	・	・	・
Stipa capillacea	・	・	・	・	・	・	・	1・2	・	・	・
Agrostis sp.	・	・	・	・	・	・	・	+	・	・	・
Bupleurum sp.−2	・	・	・	・	・	・	・	+	・	・	・
Comastoma sp.	・	・	・	・	・	・	・	+	・	・	・
Astragalus strictus	・	・	・	・	・	・	・	+	・	・	・
Stellaria sp.	・	・	・	・	・	・	・	+	・	・	・
Silene sp.	・	・	・	・	・	・	・	+	・	・	・
Taraxacum sp.	・	・	・	・	・	・	・	・	+・2	・	・
Stellaria sp.	・	・	・	・	・	・	・	・	+	・	・

Comastoma sp.	·	·	·	·	·	·	·	·	·	+·2	·
Ranunculus pulchellus var. stracheyanus	·	·	·	·	·	·	·	·	·	+	·
Lagotis brevituba	·	·	·	·	·	·	·	·	·	+	·
Kobresia prainii	·	·	·	·	·	·	·	·	·	·	2·2
Arenaria sp.	·	·	·	·	·	·	·	·	·	·	1·2
Taraxacum sp.	·	·	·	·	·	·	·	·	·	·	1·1
Sinochasea trigyna	·	·	·	·	·	·	·	·	·	·	+·2
Valeriana sp.	·	·	·	·	·	·	·	·	·	·	+
Heracleum mittefolium	·	·	·	·	·	·	·	·	·	·	+

Alpine Tundra in China & Tibet, 2006

1: Draba eriopoda-Cerastium caespitosum community

2: Ophioglossum nudicaule-Saussurea kingii community

3: Potentilla parvifolia-Arenaria capillaris var. glandulosa community

Running Nr.	1	2	3
Releve Nr.	Q-16	T-7	T-14
Latitude	36	29	29
	22	20	3
	43	526	521
Longitude	101	90	88
	28	11	0
	208	215	521
Date	9	9	9
	17	21	22
Exposition	NW	SE	NW
Slope	40	10	5
Elevation	3480	3743	4562
Height of vegetation (cm)	15	5	3
Coverage of vegetation (%)	5	10	10
Coverage of Moss layer (%)	-	-	-
Quadrat size	2X2	1X1	2X2
Species Nr.	5	7	5
Differential species of communities:			
Cerastium caespitosum	1・1	・	・
Draba eriopoda	1・1	・	・
Stellaria chamaejasme	+・2	・	・
Polygonum viviparum	+・2	・	・
Arenaria przewalskii	+	・	・
Saussurea kingii	・	1・1	・
Chenopodium botys	・	+・2	・
Ophioglossum nudicaule	・	1・1	・
Corispermum pseudofalcatum	・	1・2	・
Tribulus terretris	・	+	・
Eragrostis minor	・	+	・
Artemisia demisa	・	+	・
Arenaria capillaris var. glandulosa	・	・	1・1
Chenopodium sp.	・	・	+・2
Potentilla parvifolia	・	・	+
Dimorphostemon glandulosum	・	・	+
Lasiocaryum densiflorum	・	・	+

Appendix 2

Alpine Tundra in China & Tibet, 2006

a: *Artemisia sacrorum-Stipa krylovii* community

b: *Artemisia scoparia-Sophora moorcroftiana* comminity

	a	b	
Running Nr.	1	3	2
Releve Nr.	Q-24	T-16	T-1
Latitude	36	29	29
	5	8	31
	429	437	386
Longitude	101	88	90
	46	8	56
	2	437	157
Date	9	9	9
	17	22	21
Exposition	NW	SE	SE
Slope	10	10	20
Elevation	2935	4092	2610
Height of vegetation (cm)	30	50	25
Coverage of vegetation (%)	80	30	50
Coverage of Moss layer (%)	-	-	-
Quadrat size	3X3	5X5	5X5
Species Nr.	30	21	8
Differential species of communities:			
Stipa krylovii	3・3	・	・
Leontopodium leontopodioides	2・2	・	・
Hedysarum algidum	2・2	・	・
Heteropappus altaicus	2・2	・	・
Poa sinoglauca	2・2	・	・
Potentilla multucaulis	2・2	・	・
Allium cyaneum	1・2	・	・
Dracocephalum tanguticum	1・2	・	・
Thermopsis lanceolata	1・2	・	・
Artemisia gmelinii	1・1	・	・
Artemisia sacrorum	1・1	・	・
Koeleria cristata	1・1	・	・
Oxytropis imbricata	1・1	・	・
Polygala sibirica	1・1	・	・
Potentilla biforca	1・1	・	・
Potentilla tanacetifolia	1・1	・	・
Artemisia scoparia	・	2・2	1・1
Sophora moorcroftiana	・	1・2	+
Carex cf. scabra	2・2	・	・
Orizopsis sp.	2・2	・	・
Elymus nutans	+・2	・	・
Galium verum	+・2	・	・
Melilotoides ruthenica	+・2	・	・
Stellaria chamaejasme	+・2	・	・
Phlomis dentosa	+・2	・	・
Potentilla multifida	+	・	・
Roegneria breviglumis	+	・	・
Thalictrum alpinum	+	・	・
Ixeridium gramineum	+	・	・
Androsace tibetica	+	・	・

Bupleurum smithii	+	・	・
Gentiana straminea	+	・	・
Stipa capillacea	・	1・2	・
Ceratostigma ulicinum	・	1・2	・
Aretamisia xigazeensis	・	1・1	・
Carex scabrirostris	・	1・1	・
Cotoneaster microphyllus	・	1・1	・
Imperata cyrindricha var. minor	・	1・1	・
Inula hoekeri	・	1・1	・
Saussura kingii	・	1・1	・
Compositae	・	1・1	・
Eragrostis minor	・	+・2	・
Poa crymophila	・	+・2	・
Silene subcrelecea	・	+・2	・
Carex big	・	+・2	・
Astragalus strictus	・	+	・
Corispermum pseudofalcatum	・	+	・
Heteropappus gouldii	・	+	・
Lagotis brevituba	・	+	・
Pedicularis alaschanica ssp. tibetica	・	+	・
Labiatae wood	・	+	・
Aristida tsangpoensis	・	・	3・3
Astragalus sp.	・	・	1・1
Astragalus tibetanus	・	・	+
Orinus thoroldii	・	・	+
Pennisetum centrasiaticum	・	・	+
Calyopteris trichophara	・	・	+

2) Vegetation Zonation of Northern Asia

Pavel V. KRESTOV (*Institute of Biology & Soil Science, Vladivostok 690022, Russia*)

The vegetation cover of Northern Asia is very heterogeneous, due to two basic climatic gradients. The wide latitudinal range results in major climatic changes, from the Arctic zone in the north to the northern temperate zone in the south. The location near the Pacific Ocean causes another type of climatic gradient, that of continentality. The climate of the oceanic islands is suboceanic, with cold summers and mild winters. In the continental interior the climate is ultra-continental, with very cold winters (absolute minimum -72°C at Oymyakon) and warm summers (absolute maximum 43°C at the same location). The climatic differences cause changes in the vegetation, expressed from north to south as a sequence of phytogeographical zones:

(1) Arctic

(2) Subarctic

(3) Boreal

(4) Temperate

This sequence of vegetation zones is commonly accepted in the Russian school of phytogeography, with east-west differentiation reflecting the continentality gradient.

The Russian Far East is subdivided commonly into five continentality sectors:

(1) Suboceanic

(2) Maritime

(3) Subcontinental / Submaritime

(4) Continental

(5) Ultra-continental

Vegetation in each continentality sector reflects the change from damp, relatively seasonal, even oceanic climates near the coast to dry, seasonally contrasting climates in the interior.

The sectoral nature of the vegetation zonation is reflected by subdividing zones or subzones into phytogeographical areas with continentality-dependent features in the vegetation. The main characteristics of these phytogeographical areas are summarized briefly below.

General publications on vegetation, floristics, bioclimatology:

Krestov, P.V. 2003. Forest vegetation of Easternmost Russia (Russian Far East) // Forest vegetation of Northeast Asia. - Dordrecht. P. 93-180. Please download pdf from http://www.biosoil.ru/files/00000051.pdf

Qian H., Krestov P., Fu P.-Y., Wang Q.-L., Song J.-S., Chourmouzis C. 2003. Phytogeography of Northeast Asia // Forest vegetation of Northeast Asia. - Dordrecht. P. 51-91. Please download pdf from http://www.biosoil.ru/files/00000052.pdf

Kostak M., Krestov P.V., Okitsu S. 2003. Basic Geomorphological and Geological Characteristics of Northeast Asia // Forest vegetation of Northeast Asia. - Dordrecht. P. 33-49.

Qian H., Song J.-S., Krestov P., Guo Q., Wu Z., Shen X., Guo X. 2003. Large-scale phytogeographical patterns in East Asia in relation to latitudinal and climatic gradients // Journal of Biogeography. - Vol. 30. P. 129-141. Please download pdf from http://www.biosoil.ru/files/00000053.pdf

Krestov PV, Nakamura Y. 2007. Climatic controls of forest vegetation distribution in Northeast Asia // Berichte der REINHOLD-TUXEN-GESELLSCHAFT. - Vol. 19. P. 131-145. Please download pdf from http://www.biosoil.ru/files/00006053.pdf

Nakamura Y., Krestov P.V., Omelko A.M. 2007. Bioclimate and vegetation complexes in Northeast Asia: a first approximation to integrated study // PHYTOCOENOLOGIA. - Vol. 37. N 3-4. P. 443-470. Please download pdf from http://www.biosoil.ru/files/00006037.pdf

ARCTIC ZONE

Arctic deserts

In northeastern Asia only Wrangell and Gerald Islands are in the zone of Arctic Deserts, which are characterized by the lack of a closed vegetation cover. Large areas on the islands are covered by talus or rock outcrops. Crustose and foliose lichens (species of *Gyrophora*, *Lecidea*, and *Rhizocarpon*) are most abundant on the stony substrates. On the sites with accumulations of fine soil, fruticose lichens (*Alectoria*, *Cetraria* and *Cladonia*) and mosses (mainly *Andraea papillosa*, *Pogonatum capillare*, *Rhacomitrium lanuginosum* and *Tetraplodon mnioides*) form the sparse cover. The vascular plants are represented by *Douglasia ochotensis*, *Artemisia glomerata*, *Papaver polare*, *Saussurea tilesii*, *Saxifraga funstonii*, etc. The bryophytes and flowering plants are scattered and not numerous.

Arctic tundra

The coast of the Arctic Ocean and all of the Chukotka Peninsula north of 65°N are covered by tundra vegetation. The Tundra Zone is subdivided into two subzones: typical Arctic tundra along the Arctic coast and lichen tundra as the main zonal vegetation on the Chukotka Peninsula and lower Anadyr River basin.

The Far Eastern sectors of the Arctic Polar Desert and Tundra are differentiated from the rest of the circum-Arctic zone by the presence of so-called Beringian plant species, which are also common to Alaskan and eastern-Canadian sectors of the Arctic zone.

Tundra vegetation is characterized by a closed, one-layer cover composed mainly of perennial plants, especially dwarf-shrubs, mosses and lichens, and by a lack of larger shrubs and trees. Most typical tundra plants have their renewal buds no higher than 20–30 cm above the ground and reproduce mainly vegetatively. All tundra plants are adapted to the short vegetative season with its long period of daylight.

Tundra communities vary in composition depending on site edaphic and climatic conditions. Regions along the Arctic coast are characterized by predominance of sedge and heath communities with *Carex* spp., *Eriophorum vaginatum*, *Vaccinium uliginosum*, *Betula exilis* and leafy mosses. On the Chukotka Peninsula sedge communities are also important, but lichen communities with *Cladina* spp. and some ericaceous dwarf shrubs increase.

SUBARCTIC ZONE

Beringian woodland

This area is characterized by the dominance of dwarf trees, the conifer *Pinus pumila* and broad-leaved *Alnus fruticosa* s.l. This vegetation occurs widely in the basins of the Anadyr and Penzhina Rivers, on the Koriakskiy mountain range, northern half of Kamchatka, southernmost Kamchatka (Lopatka Cape), and on the Commander Islands and northern Kuril Islands. Kolesnikov (1955) proposed that the presence of more or less extensive tundra patches on zonal sites should be a criterion for distinguishing the Beringian woodland area. By this criterion the Beringian woodland area extends due south along the coast of the Sea of Okhotsk to Magadan, including the northern Koni Peninsula. From a total area of 35 million hectares occupied by Pinus pumila communities, 25 million hectares represent its horizontal zone, stretching from the Kolyma River to Koryakia and northern Kamchatka, roughly between latitude 60 and 68°N.

Although the Beringian woodland occurs only in the submaritime, maritime and suboceanic sectors, the vegetation does gradually change from mainly *Pinus pumila* thickets inland to mainly *Alnus fruticosa* thickets in coastal areas. Scattered *Larix cajanderi* trees are a stable component of the vegetation, increasing inland. These can form small forest patches in river valleys and on southern slopes. Mires with *Carex appendiculata*, *Eriophorum* spp. and *Sphagnum* spp. occur widely in areas on permafrost. Small patches of forest dominated by *Populus suaveolens* and *Chosenia arbutifolia* occur in river valleys, in combination with wet grass meadows.

A main feature of dwarf-pine stands is the lack of any generation structure in the canopy due to the continuous growth. Old-growth stands typically look like completely closed communities, with little or no moss cover and with very few herbs or dwarf shrubs. A dwarf-pine community may reach this stage after 100–150 years. Dwarf pine may regenerate from seeds within occasional gaps appearing after disturbances or forming above dying old basal parts. The process of natural regeneration in the old-growth communities has not been studied.

Dwarf pine is an important species in primary succession on new subalpine and subarctic substrates, such as coastal sand dunes, lava flows and ash deposits after volcanic eruptions, and areas affected by wildfires. Seedlings of *Pinus pumila* may appear on the new substrate a year after disturbance, growing from seeds brought by the nutcracker *Nucifraga caryocatactes* ssp. *macrorhynchos* in eastern Siberia or *N. caryocatactes* ssp. *kamtschatkensis* in the northern Far East. In the first 40–60 years dwarf pine grows in length, forming a well-developed crown by the end of the period. New shrubby trees never form a closed cover on new substrates or on space made available after fire, and the whole stand looks like a well spaced woodland, with tundra communities developing between the shrubs. Over all this period, new seedlings appear on the pine-free spaces, gradually forming a closed stand by a stand age of 100–150 years.

Light deficiency under the pine canopy limits the development of herb and moss layers, but these layers can form in old-growth stands with long branches. There is a complex of species closely related to the pine thickets in the subarctic or the subalpine belts: *Rhododendron aureum*, *Carex rigidioides*, *Salix berberifolia*, and *Bistorta elliptica*. Over the whole range of dwarf-pine thickets, the main companions are: *Alnus fruticosa*, *Betula exilis*, *B. middendorffii*, *Calamagrostis lapponica*, *Carex lugens*, *Empetrum nigrum*, *Eriophorum vaginatum*, *Aconogonum tripterocarpum*, *Salix fuscescens*, *Petasites frigidus*, *Pinguicula spathulata*, etc. Also, *Arctous alpina*, *Cassiope ericoides*, *C. tetragona*, *Diapensia obovata*, *Hierochloë alpina*, *Loiseleuria procumbens*, *Salix glauca* and *Saussurea alpicola* appear at the contacts between dwarf-pine thickets and tundra communities. In dwarf-pine communities within forest zones, on a wide range of ecotopes, *Pinus pumila* may form stands together with *Larix cajanderi*, which is present as solitary trees. Such stands may also include *Andromeda polifolia*, *Calamagrostis langsdorffii*, *Carex appendiculata*, *C. globularis*, *Ledum palustre*, *Lycopodium annotinum*, *Linnaea borealis*, *Maianthemum bifolium*, *Pentaphylloides fruticosa*, *Rosa acicularis*, *Salix myrtilloides*, *Spiraea betulifolia*, *Vaccinium myrtillus*, etc.

Eastern Siberian woodland

The dwarf-pine zone does not occur in continental areas (Kolyma River), where the arctic zone borders the *Betula divaricata / exilis* – willow scrub with scattered larch trees and the forest patches. This association class is common in the north, north of the Suntar-Hayat Mountains but including their southern foothills. Communities of this type form the alpine treeline in mountains throughout the continental areas. This area has the most severe climate in Asia, including the "coldness pole" of Oymyakon, where an absolute minimum temperature of -72°C was recorded in 1964 (Anonymous 1966–1971). Average annual precipitation ranges from 140 to 170 mm, with 75% falling in summer. At high elevations the precipitation increases to 200–250 mm. Only 40–90 days in a year have a temperature above 10°C. Only 32% of this territory is covered by forests, which occur mainly in depressions and on lower mountain slopes. Nearly all larch communities in the area, beside the birches and willows, have *Pinus pumila* in the understorey, which may form a closed layer or be present only individually. Species with subarctic or arctic distribution characterize this vegetation type: *Salix arctica*, *Arctous erythrocarpa*, *Aconogonum tripterocarpum*, *Salix reticulata*, *S. pulchra*, *S. tschuktschorum*, *Cassiope tetragona*, etc.

The prevalence of dry soil promotes the wide distribution of larch-lichen communities. These occur on southern slopes and ridges with the most severe droughts appearing in summer. The 8–10 m tall larch forms an open canopy (20–40%). Lichens of the genera *Cladonia* and *Cetraria* cover the ground. *Carex vanheurckii*, *Hierochloë alpina* and *Aconogonum tripterocarpum* occur sporadically. The most productive larch stands, reaching 30 m in height, are found in the moderately drained river valleys. These communities have a well-developed shrub layer composed of *Sorbaria sorbifolia*, *Lonicera caerulea*, and *Rosa acicularis*, and a well-developed herb layer composed of *Calamagrostis langsdorffii*, *Cacalia hastata*, *Urtica platyphylla*, etc.

Publications on phytosociology of subarctic zone:

Manuscript attached. KRESTOV, ERMAKOV, OSIPOV, NAKAMURA. A PHYTOSOCIOLOGICAL STUDY OF LARIX CAJANDERI AND LARIX GMELINII FORESTS OF NORTHEAST ASIA. Folia Geobotanica – in part of Betuletea glanduloso-divaricatae

BOREAL ZONE

Eastern Siberian larch area

The larch area is one of the largest homogeneous phytogeographical areas in the whole circum-boreal zone. It stretches from the tundra (continental regions) and Beringian woodlands (maritime regions) in the north to the coast of the Sea of Okhotsk (northern boreal zone) and Amur basin in the south. Larch forests extend westward to the Yenisey River, where they are replaced by spruce (*Picea obovata*) forests. The main feature of the area is the dominance of *Larix cajanderi* s.l. on zonal sites.

Despite the great variety of ecological regimes and climatic conditions in larch communities, the species composition remains surprisingly homogeneous over the whole range from south to north and from west to east. Several seral species, mainly *Betula platyphylla*, *Populus suaveolens* and *Alnus hirsuta*, may accompany *Larix cajanderi* on zonal sites. River valleys are occupied by forests of *Populus suaveolens*, *Salix udensis*, *S. rorida* and *Chosenia arbutifolia*.

The dominance of shade-intolerant larch over such a large territory is caused by the severe climatic conditions and permafrost, which can be tolerated only by *Larix cajanderi*.

Since there are very wide plains in this region, most larch stands are represented by a wet sere including the larch communities with *Ledum palustre* and with different *Sphagnum* spp. They are common in the north, in the Zeya-Bureya Plain, and the last in the lower Amur basin. Nearly all stands have an open canopy and low productivity. Communities with *Ledum palustre* occur mainly on flat, moderately drained uplands. Their undergrowth involves *Ledum palustre* (dominant) mixed with *Vaccinium uliginosum*, *Betula divaricata* and a moss cover of *Pleurozium schreberi*. A sphagnum type is similar to that in the previous vegetation type. The larch forests with *Carex appendiculata* are restricted to lowlands in the southern part of the range. These sites have a high but non-stagnant water table. The undergrowth contains *Carex appendiculata*, *Myrica tomentosa*, *Chamaedaphne calyculata*, and *Eriophorum* spp. as dominant species. Important companions, usually increasing after fire, are *Calamagrostis langsdorffii* and *Chamerion* (*Epilobium*) *angustifolium*, which normally occur on the tops of sedge mounds. *Carex globularis*, *Aulacomnium palustre*, and *Sphagnum girgensohnii* occur in the lower areas between the sedge mounds.

Kamchatka conifer forests

This area lies in the middle of the Kamchatka Peninsula, between the Sredinniy and Vostochniy mountain ranges. Larch and spruce (*Picea yezoensis*) form the forest here, in the locally submaritime climate made possible by the mountains that block both Okhotsk and Pacific air masses. The area is surrounded by Beringian woodlands to the north, with *Alnus fruticosa* as a dominant, and by birch (*Betula ermanii*) forests plus tall-herb meadows to the south, east and west.

Spruce and larch forests represent zonal vegetation in the area. Although this is not the northernmost extent of spruce, it is the coldest part of the geographical range of *Picea yezoensis*. The spruce forests of the area are characterized by the predominance of circum-boreal or Pacific-boreal species in all layers.

Picea jezoensis forests have the simplest structure and poor species composition. The tree layer contains only *Picea yezoensis*, with some possible admixture of *Betula ermanii* at high elevations. Solitary individual trees of broad-leaved *Sorbus sibirica* occur under the main canopy. After severe fires these forests recover through a *Larix cajanderi* stage. Occasionally admixtures of spruce, form the young canopy, and a canopy of larch can be found at different stages of breakdown.

On Kamchatka we noted 110 vascular species and 15 main species of ground mosses. Most vascular boreal geoelements occur widely across the circum-boreal zone. The most important cenobiogroups are taiga small herbs *Maianthemum bifolium*, *Chamaepericlymenum suecicum*, etc.; ferns *Diplazium sibiricum*, *Dryopteris expansa* and *Phegopteris connectilis*; herbs *Streptopus streptopoides*, *Saussurea oxyodonta*, *S. pseudotilesii* (only on Kamchatka), *Solidago spiraeifolia* and *Veratrum alpestre*; the taiga dwarf shrub

Vaccinium vitis-idaea; and taiga shrubs *Rosa acicularis*, *Juniperus sibirica*, *Spiraea beauverdiana* and *Ribes triste*. *Chamaepericlymenum suecicum* and *Lonicera chamissoi* characterize this vegetation type.

Larix cajanderi forests in this area dominate on larger area than spruce and represent both natural and seral communities that occur mainly on sites with intensive disturbance regimes caused by fires or volcanic activity, or in areas with a locally subcontinental climate lying to the south of the "conifer island". The structure and floristic composition of the larch forests are similar to those in the continental part of eastern Siberia. *Populus suaveolens*, *Chosenia arbutifolia* and *Salix udensis* forests represent the valley vegetation of the area. Grass meadows are typical for the floodplain of the Kamchatka River.

Kamchatka meadow-birchwood area

Stone birch (*Betula ermanii*) forms forests on zonal sites in southern Kamchatka and the middle Kuril Islands (Iturup, Urup), in a severe sub-oceanic climate with cold summers, mild winters, and nearly equal distribution of precipitation throughout the year. Another important zonal vegetation type, the tall-herb meadow, develops on areas of snow accumulation. Both vegetation types characterize the cold, wet, sub-oceanic climate within the northern boreal zone.

Betula ermanii forests occupy zonal sites (mesic, drained, gently sloping) and have the widest distribution in the area of stone-birch forests. The differences in understorey vegetation reflect differences in the soil nutrient regime: tall herbs indicate rich soils and medium boreal herbs indicate medium soils. Diagnostic species for the tall-herb communities are *Senecio cannabifolius*, *Filipendula camtschatica* and *Cirsium schantarense*, which can dominate in herb layers that may reach 3 m in height. Important companions in the south are *Angelica ursina* and *Peracarpa circaeoides*. Because of the dense herb layer, a middle stratum is absent. A lower stratum may occur as fragmented synusiae of suppressed small taiga herbs, under the tall-herb stratum: *Maianthemum dilatatum*, *Trientalis europaea* and *Circaea alpina*. The communities with boreal herbs have a well-developed layer of medium herbs, of which diagnostic species are: *Artemisia opulenta*, *Geranium erianthum*, *Saussurea pseudotilesii*, *Solidago spiraeifolia*, *Thalictrum minus* and *Moehringia lateriflora* (in lower stratum). The lower stratum is well developed, with the prevalence of *Maianthemum dilatatum*, *Lycopodium clavatum*, *Chamaepericlymenum canadense*, *Rubus arcticus*, etc.

Alnus fruticosa thickets occur on saturated sites throughout the Beringian Woodland area and Kamchatka and forms pure stands on zonal sites in easternmost Koryakia, southeastern Kamchatka, and on the northern Kuril Islands (Grishin 2000). Within this area, *Pinus pumila* occupies mainly mountain ridges, very steep slopes and well-drained substrates, such as alluvium deposits, coarse morainal deposits and surfaces of old lava flows. *Alnus fruticosa* occupies a wide range of ecologically different sites from sea level to 600–700(900) m.

Alnus fruticosa shows close relationships with many parameters of the subarctic suboceanic climate, such as the Kira warmth index, winter precipitation (snow depth in valleys may reach 5 m), the relatively narrow annual temperature range (only 49°C on the northern Kurils), frequent winter thaws (absolute January maximum of +13°C in the northern Kurils (Anonymous 1966–1971) and very low insolation in summer, due to fog and cloudiness (total hours <1000–1500 per year).

Variation in the community types is caused mainly by edaphic characteristics. *Alnus fruticosa* with mixed mesic herb layer are widespread on drier sites with medium soil nutrient regimes. The main zonal communities on the northern Kurils belong to the *Dryopteris expansa* and *Glyceria alnasteretum* types.

Populus suaveolens, *Chosenia arbutifolia* and *Salix udensis* forests represent the valley vegetation. Their characteristic features are dominance by tall herbs in the herb layer.

Okhotskia dark-conifer forests

Picea yezoensis is the dominant species in the Western Okhotsk Dark-Conifer Area, occurring in the submaritime and maritime climates in the middle and southern parts of the boreal zone. Spruce forests within this area cover the southern Dzhugdzhur Range, eastern Stanovoy Range, the area between the Amur and Uda Rivers, the northern Sikhote-Alin Range, all of Sakhalin, Iturup (southern Kurils), and the Pacific side of Hokkaido. On the north and west, this area borders the eastern Siberian Larch area. On the south it contacts the northern-temperate mixed-forest area.

Spruce stands on the mainland normally involve at least two tree species, *Abies nephrolepis* and *Picea yezoensis*, forming a dense forest canopy. *Picea obovata* (in the west) and *Picea koraiensis* (in the south) may also occasionally be present in the canopy. Differences in eco-biological characteristics of fir and spruce cause well-expressed cyclic dynamics of these spruce-fir forests, with dominance by different species in different stages of stand development. In addition to conifers, various broad-leaved species characterize this association class. The canopy of spruce-fir forests may contain individual trees or groups of *Sorbus amurensis* or *Betula ermanii* (at higher elevations). *Acer ukurunduense* occurs and occasionally forms a stratum under the canopy. In the south, spruce-fir forests may be enriched by temperate tree species such as *Acer mono*, *Betula costata*, *Fraxinus mandshurica*, *Pinus koraiensis*, or *Tilia amurensis*. Normally the tree layer shows only poor further stratification, if any; if differentiated, the second stratum contains the same species as the canopy but with greater amounts of *Abies nephrolepis*.

Spruce stands on Sakhalin, in the southern Kurils and on Hokkaido are formed under maritime and oceanic climates. The main difference from the mainland forests is the presence of *Abies sachalinensis* in the tree layer. In contrast to *A. nephrolepis*, *A. sachalinensis* in the south can form normal, self-regenerating mono-dominant stands, even without spruce. In these forests *Sorbus commixta* may occur as individuals in the canopy, and *Acer ukurunduense* usually occurs in the understorey as solitary trees or in groups. At high elevations *Betula ermanii* occurs in the canopy. In the south, on the Krilion Peninsula of Sakhalin, on Kunashur and on Hokkaido, temperate tree species such as *Kalopanax septemlobus*, *Fraxinus mandshurica*, and *Tilia japonica* occur as individuals in the canopy. The tree layer may be somewhat stratified into two strata with the same species composition.

The range of *Picea glehnii* forests in Russia includes only the Mereya basin and the Aniva Peninsula on southernmost Sakhalin. In this area *Picea glehnii* stands occur mainly in mires and on slopes, sharing these sites with *Larix cajanderi*. *Picea glehnii* also occurs on Kunashir, where it forms monodominant communities in mires and mountain slopes. On saturated sites in floodplains *Picea glehnii* forms stands with *Larix cajanderi*. *Abies sachalinensis* and *Picea yezoensis* may occur solely, and trees are suppressed. *Ledum palustre* dominates in the understorey. *Sphagnum fuscum*, *S. palustre* and *S. nemoreum* form large ground cushions, with patches of *Polytrichum commune* between them. This association group is characterized by the presence of *Rubus chamaemorus* and *Betula ovalifolia*.

Extensive fires decreased the modern range of spruce forests, with secondary larch forests replacing them. Larch forests are the second important vegetation formation in the area. If seed sources are present and wildfires do not recur, spruce can replace larch on zonal sites within 100–300 years after fire.

The basic vegetation types in river valleys are larch forests and woodlands, *Populus suaveolens* and *P. maximowiczii* forests, and *Chosenia arbutifolia*, *Salix udensis* and *S. rorida* forests. Grass meadows with *Calamagrostis purpurea* develop in the lowest areas. Sedge (*Carex appendiculata*) and sphagnum bogs occur widely across the zone, in depressions with cool-air drainage over permafrost and on poorly drained sites.

Publications on phytosociology of boreal zone:

Krestov P.V., Nakamura Y. 2002. Phytosociological study of the Picea jezoensis forests of the Far East // Folia Geobotanica. - Vol. 37. N 4. P. 441-474. Please download pdf from http://www.biosoil.ru/files/00000069.pdf

Manuscript attached. Krestov, Nazimova, Stepanov, DellaSala. The Temperate Rainforest Ark of Northern Asia

Manuscript attached. KRESTOV, ERMAKOV, OSIPOV, NAKAMURA. A PHYTOSOCIOLOGICAL STUDY OF LARIX CAJANDERI AND LARIX GMELINII FORESTS OF NORTHEAST ASIA. Folia Geobotanica – in part of Betuletea glanduloso-divaricatae

In these days I will accomplish a manuscript on Kamchatka vegetation

NORTHERN SUBZONE OF TEMPERATE ZONE

This zone lies in the basin of the Amur River and on the spurs of the Sikhote-Alin, Badzhal and Lesser Hingan mountain ranges. The Amur valley permits oceanic air masses to penetrate deeply into the interior, shifting the eastern boundary of the continental climate considerably further inland. In addition, the continental cold air masses continue building over the winter, creating a strong contrast between summer and winter. Winter temperatures are extremely low for a maritime region at 40° latitude (-20°C mean for January), and summer temperatures are relatively high (August means to +22°C), with high humidity. The high mean annual temperatures (+2 to +5°C), with the strong seasonal contrast, permit occurrence of a great variety of vegetation types on zonal sites. The continentality gradient causes a change in vegetation that ranges from drought-tolerant oak forests in the interior to species-rich mixed broadleaf-conifer forests in coastal areas. Three areas are recognized in this northern temperate zone.

Daurian broad-leaved forests

Most of this area lies in northeastern China, reaching northeastern Mongolia in the west. On the Russian territory it appears in the upper Amur basin, called Dauria, and in the basin of Lake Hanka. These areas have been strongly influenced by human activity for many centuries, which partly explains the current state of vegetation in the area. The modern vegetation cover contains meadows, bogs and forests in nearly equal proportions. Most meadows and some bogs areas were transformed into agricultural lands. The basic forest type is Mongolian oak (*Quercus mongolica*), forming pure stands or mixed with *Betula davurica*. All components of the forest communities are drought tolerant and fire resistant. Fire is the most important factor influencing natural selection in the oak forests. Meadows in the zone occur on sunny, well-drained slopes (steppe-like meadows) and in lowlands next to boggy vegetation. The characteristic feature of the meadows is the presence of xeric and xero-mesic herbs and grasses (*Cleistogenes kitagawae*, *Stipa baicalensis*, *Arundinella anomala*, different species of *Astragalus*, *Galium*, *Scabiosa*, *Allium*, and *Artemisia*, etc.). Mesic and hygric meadows dominated by *Miscanthus sacchariflorus* and *Calamagrostis langsdorffii* occur in lowlands. *Pinus densiflora* (near Lake Hanka), *P. sylvestris* (in the upper Amur), *Armeniaca sibirica*, and *Ulmus macrocarpa* form small patchy stands on hill slopes and ridges.

Manchurian mixed forests

This area of temperate mixed forests (broad-leaved trees plus five-needled Korean pine) lies on the spurs of the Sikhote-Alin range and the southern spurs of the Lesser Hingan, Bureinskiy and Badzhalskiy ranges. The main vegetation type is mixed forests co-dominated by *Pinus koraiensis* and various broad-leaved tree species: *Tilia amurensis*, *T. mandshurica*, *Fraxinus mandshurica*, *Quercus mongolica*, *Betula costata*, *Abies holophylla* (only south of 44°N), *Kalopanax septemlobus*, *Phellodendron amurense*, and *Ulmus japonica*. In most communities the number of tree co-dominants is 3–5 species. At 600–800 m above sea level, the temperate communities may be enriched by boreal dominants *Picea yezoensis* and *Abies nephrolepis*. Other vegetation types in the area include broad-leaved valley forests of *Ulmus japonica* and *Fraxinus mandshurica* on old, stable parts of river valleys; *Populus maximowiczii* and *Populus koreana* (in fact close species) on younger parts of river valleys; and *Chosenia arbutifolia* on fresh alluvial deposits. Poorly drained parts of the Ussuri valley are occupied by grass meadows.

Old-growth forests in the area have been drastically reduced in the 20th century as a result of forest exploitation and fires. Secondary forests are represented by mixed broad-leaved forests with no conifers, *Betula platyphylla* and *Populus tremula* forests, and *Quercus mongolica* forests with no conifers, depending on site ecological conditions and kind of damage.

The mixed forests (various broad-leaved trees + Korean pine) of the Russian Far East are a vegetation complex combining some peculiarities of both nemoral and boreal vegetation. The mixed forest is the zonal vegetation type in the submaritime sector in the northern temperate subzone. These forests occur in the Russian Sikhote-Alin range and in northeastern China (Changbai, Lao-ye and Lesser Hingan mountains). Relatively isolated tracts of forest with Korean pine (*Pinus koraiensis*) are found also in southern Korea and on Honshu island of Japan, but these stands with Korean pine belong to different vegetation types.

The mixed broadleaf-Korean pine forests form lower and middle vegetation belts from sea level to 800–900 m, extending in the south as high as 1100–1200 m, coexisting and closely interacting with spruce, larch, and oak forests. The rather large north-south range of this forest type and sharp transition from oceanic monsoonal to continental climate have resulted in quite diverse vegetation within the mixed-forest zone. This has been reflected in various schemes of geobotanical districts and on vegetation maps. This region was not glaciated during the Pleistocene or Holocene, although it currently does border the permafrost area to the north. The strong modern climatic gradients, past marine transgressions, and long period of uninterrupted vegetation development have permitted much mixing of northern and southern as well as maritime and steppe elements in the regional flora and vegetation.

The occurrence of the mixed forest between clearly distinguishable boreal and temperate zones has posed the question whether the mixed forest is temperate or boreal. In recent decades, phytogeographers seem to have favored the idea that it is temperate. In 1958 M. Tatewaki related it to the special "Pan Mixed Forest Zone," temperate in nature, which also includes climatically and physiognomically similar vegetation of central Europe (Carpathian and Tatra mountains) and of eastern North America (northern Appalachians and around the Great Lakes), interrupted in continental interiors by steppes or deserts. Hämet-Ahti et al. (1974) treated this vegetation as a northern subzone of the temperate zone; Sochava (1969b) treated it as nemoral and Kolesnikov (1963) as temperate. Russian authors have traditionally placed this forest in a special so-called 'Far Eastern coniferous-broadleaf forest area' (Ya. Vasiliev 1947, Kolesnikov 1961, Lavrenko 1950). In 1956 Kolesnikov suggested naming it the East Asian area of mixed coniferous-broadleaf forests and related it to the temperate zone. The boundaries of the area coincide generally with those of the Manchurian floristic area distinguished by Komarov in 1901 and still used by botanists (Komarov 1934–1964, Kharkevich 1985–1996).

Northern Japanese mixed forests

The temperate vegetation in suboceanic southern Sakhalin and the southernmost Kurils (Habomai) differs from the temperate vegetation on the mainland, in terms of dominants and species composition, due to the influence of the Japanese flora. The main vegetation type is mixed *Abies sachalinensis-Quercus crispula* forest with sasa (short, fruticose broad-leaved bamboo). Most of the area lies on Hokkaido, north of the Kuromatsunai Lowlands, where it borders the area of *Fagus crenata* forests. The zonal vegetation in the area is mixed *Abies sachalinensis-Quercus crispula* forest with an admixture of broad-leaved species such as *Kalopanax septemlobus*, *Tilia maximowicziana*, and *Fraxinus mandshurica*.

Publications on phytosociology of temperate zone:

Nakamura Y., Krestov P.V. 2005. Coniferous forests of the temperate zone of Asia // Coniferous forests (Ecosystems of the World, Vol. 6). - . P. 163-220. Please download pdf from http://www.biosoil.ru/files/00000785.pdf

Krestov P.V., Song J.-S., Nakamura Y., Verkholat V.P. 2006. A phytosociological survey of the deciduous temperate forests of mainland Northeast Asia // PHYTOCOENOLOGIA. - Vol. 36. N 1. P. 77-150 Please download pdf from http://www.biosoil.ru/files/00000049.pdf

The Temperate Rainforest Ark of Northern Asia

Pavel V. Krestov, Institute of Biology and Soil Science, Vladivostok, Russia
Dina I. Nazimova, Institute of Forest Science, Krasnoyarsk, Russia
Nikolai V. Stepanov, Krasnoyarsk State University, Russia
Dominick A. DellaSala, National Center for Conservation Science & Policy, USA

Box 1 - Rainforest relics: sum-of-the parts

- Distributed mainly along the coast of Pacific ocean as part of the "green belt of Asia", the world longest uninterrupted gradient of forests from subarctic (70°N) to tropical latitudes. Most of the rainforests in Northern Asia is formed under influence of the Pacific monsoon. Another, smaller fragment occurs in the mountains of southern Siberia being affected mailly by Atlantic damp air masses.
- High humidity, relatively high temperature, longer growing season led to formation of the species-rich and humidity dependent Yezo spruce (*Picea jezoensis*), Sakhalin fir (*Abies sachalinensis*), and several hardwoods (*Fraxinus* spp., *Tilia* spp., *Phellodendron amurensis*, *Juglans* spp.) on the Russian Far East and wite birch (*Betula pendula*), Siberian fir (*Abies sibirica*), Siberian stonepine (*Pinus sibirica*) humidity-dependent forests in the mountains of Southern Siberia that could be called the rainforests
- High humidity, relatively low temperature, shorter growing season, and extremely heavy snowfall create unigue ecological conditions supporting alder (*Alnus fruticosa*), Siberian dwarf-pine (*Pinus pumila*) and Ermann's birch (*Betula ermannii*) forests that could be called snowforests.
- Rainforests of the mountains of southern Siberia represent relic vegetation of modern refugium that occurs in continental areas of Northern Asia near the steppe zone (dry plain without trees).
- Relic moist nemoral species (species of temperate broad-leaved forests) create contrasting ecosystems with boreal (forests of northern latitudes) dominants in conditions of heavy precipitation on the mountains catching air masses from the Atlantic Ocean.
- Tall herbs are characteristic understorey plants of northern rainforests that developed in conditions of high humidity and deep snow cover in winter. Snow cover protects buds of herbs from freezing; therefore the herb cover includes many globally unique (endemic) orchids and plants with southern distribution.
- Sikhote-Alin forests, also known as 'Ussurian taiga', served as a species-rich refuge during the Pleistocene ice-age that now includes over 100 globaly unique (endemic) species of plants and animals with origins dating back to the Tertiary boreo-nemoral biome (time between extinction of dinosaurs and beginning of the Pleistocene ice-age).
- Endemics include world's largest cat, Amur tiger (*Panthera tigris atlaica*), an isolated and very small population of snow leopard (*Panthera pardus orientalis*) and the last in a world wild population of a famous medicinal plant, ginseng (*Panax ginseng*).

Northern Asia Rainforests

Northern Asia is the place where forests are dormant at least several months in the year and blanketed in winter snows. High humidity, relatively high temperature, longevity of growing season and amount of snow altogether create a great diversity of ecological conditions. Since the periods of great aridization in the Pleistocene and up until now, vegetation in the Northern Asia is transitional between dry and humid conditions from Arctic to temperate zones. Migrations of drought-tolerant Central Asian species have enriched the derivates of ancient boreo-tropical (Arcto-Tertiary) ecosystems. They occupied the niches that were vacated from the relic humidity-dependent species by very short period of drought during the growing season. Therefore, moisture on the territory of Northern Asia in the last 2.5 million years was the most valued resource for relic rainforests. Humid oceanic regions in every biogeographical zone as well as elevated habitats in montane areas are able to provide conditions that support the longest uninterrupted latitudinal forest gradient on the Pacific coast: from subarctic dwarf forests to the Malesian tropical forests. We will focus on the northern part of thi gradient, the rainforests of Northern Asia in boundaries of Russian regions of Siberia and the Far East.

Northern Asia, an area of 11 million km^2 ranging from 42°N to 73°N latitude and from 90°E to 169°W longitiude, has many contrasts in terrain, climate and vegetation. Terrain of the area varies from the world largest plains to very extensive mountain systems rising up to 4000-5000 m above sea level. Three of the 10 largest rivers in the world occur here, Lena (length 4400 km, basin area 2.490.000 km^2, water volume per second 17.000 m^3/s), Yenissei (length 5539 km, basin area 2.580.000 km^2, water volume per second 19.800 m^3/s) and Ob' (length 5410 km, basin area 2.990.000 km^2, water volume per second 12.300 m^3/s) deliver fresh water to the Arctic Ocean and cross this land uniting it as one great ecosystem. The Amur River (length 4440 km, basin area 1.855.000 km^2, water volume per second 19.800 m^3/s) is the greatest river within the Pacific Ocean basin. The basins of great rivers fringed by well distinguished mountain chains, such as Ural Mountains on the west and mountain systems of Altai, Sayany, Stanovoe nagor'e on the south, create very large and well intergated ecosystems at a continental scale (Fig. 1).

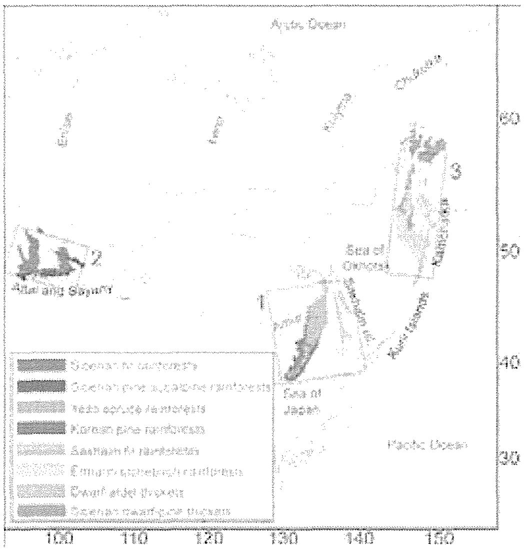


Figure 1. Area of northern Asia with main locations of the rainforests: 1 – Sikhote-Alin Mountains, 2 – Altay and Sayany Mountains, 3 – Kamchatka peninsula. Detailed vegetation maps of framed areas are given below.

Climate and zonal differentiation of rainforests

Oceans, extensive lands, great plains and mountains altogether create diversity in regional and local climates (Fig. 2). Two basic climatic gradients are characteristic to northern Asia: (1) wide latitudinal range results in major climatic changes from the Arctic zone in the north to the northern temperate zone in the south of northern Asia; and (2) location near the Pacific Ocean causes another type of climatic gradient, that of continentality. Forests that could be called the rainforests occur in 3 vegetation zones 1) temperate; 2) hemiboreal and 3) boreal.

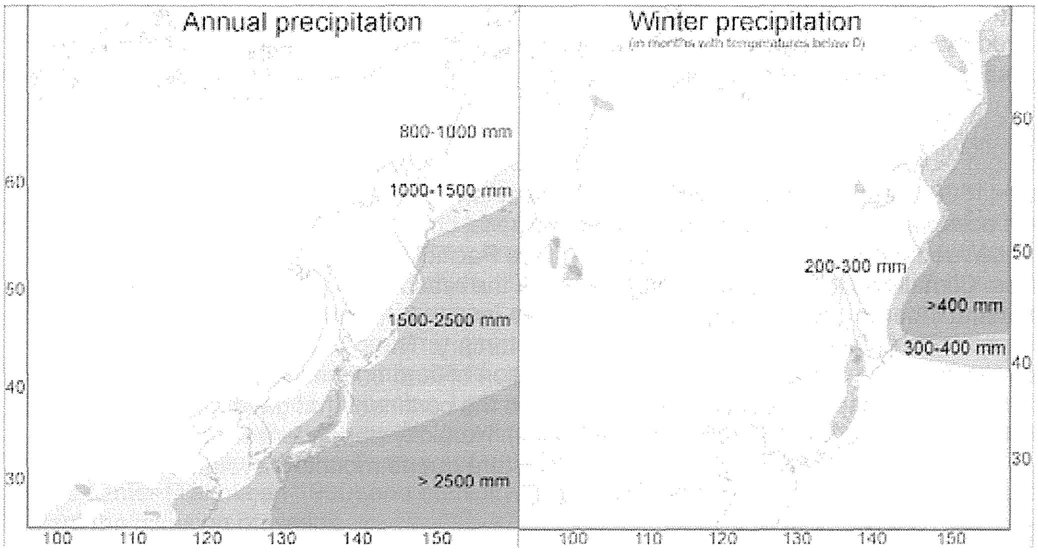


Figure 2. Distribution of annual precipitation (mm per year, left map) and winter precipitation that includes only snow (precipitation in months with the monthly temperatures below 0ºC, right map). Most of rain falls in the costal area of northern Asia, however Sayany and Altai Mountains locally deposits precipitation from the dump air coming from Atlantic. Winter precipitation demonstrates maxima in Kamchatka and, locally in the mountains of southern Siberia.

In temperate zone, high humidity, relatively high temperature, longer growing season led to formation of the species-rich and humidity dependent Yezo spruce (*Picea jezoensis*), Sakhalin fir (*Abies sachalinensis*), Korean stonepine (*Pinus koraiensis*) and several hardwoods (*Fraxinus* spp., *Tilia* spp., *Phellodendron amurensis*, *Juglans* spp.) on the Russian Far East (Nakamura & Krestov 2005).

In the hemiboreal zone, in southern Siberia, the rainforests are dominated by Siberian fir (*Abies sibirica*) in lower and Siberian stonepine (*Pinus sibirica*) in higher forest belts (Nazimova & Polikarpov 1996). They both represent relic vegetation of modern refugium that occurs in continental areas of Northern Asia near the steppe zone (dry grassy areas without trees).

Boreal zone that occupies the most on northern Asia but has the rainforets tracks only on the Pacific coast, on Kamchatka peninsula. High humidity, relatively low temperature, shorter growing season, and extremely heavy snowfall create here unigue ecological conditions supporting dwarf alder (*Alnus fruticosa*), dwarf-pine (*Pinus pumila*) and Ermann's birch (*Betula ermannii*) forests (Krestov 2003) that could be called snowforests.

Vegetation history

Some remarks on vegetation history would be very useful for understanding of modern patterns in distribution of the rainforests on this territory. The modern flora is formed on the basis of the ancestrial boreo-tropical (Arcto-Tertiary) flora that occupied very extensive areas in the temperate and polar latitudes of Northern Hemisphere (Budantsev 1999) in Tertiary. Many authors explain the species richness and high diversity of rain forests of Northern Asia by the fact that these areas have been unaffected by glaciation throughout the Pleistocene, or indeed since the high temperatures reached during the Pliocene optimum (Grichuk 1984). Most of the present species constituting the modern communities had ancestor taxa in the Tertiary ancient floras. In the most severe Pleistocene glaciations 18-20 thousand years ago Yezo spruce (*Picea jezoensis*) kept its dominant status in the lower montane belt of the Sikhote Alin range (Grichuk, 1984), which possibly was a refugium for a number of temperate species (Vasiliev 1958). Within the Sikhote Alin montane coniver forest belt several species exist in isolated localities far from their main range. These species are Ilex rugosa (central Sikhote Alin, main range on the offshore islands) and Rhododendron brachycarpum (eastern slope of the central Sikhote Alin, main range in Japan). The nemoral species Oplopanax elatus occurs exclusively in the oroboreal belt of the southern Sikhote Alin, and has never been found in temperate communities. The vegetation of the maximum stage during the last glacial period also consisted of drought-tolerant meadows and larch woodlands on the plains and dark-conifer taiga in the lower mountain belts. During the following warming, broadleaved temperate species invaded this territory from warmer and wetter regions in the south. This is indirectly proved by the great number of endemic species in the broadleaved-Korean pine and hyperhumid southern Siberia hemiboreal forests.

Most of palaeobiologists reconstructing vegetation dynamics in Pleistocene and Holocene agree in distinguishing of the following stages of vegetation development.

Pleistocene maximum 18000 years BP is characterized by lowest temperatutes and lowest humidity. Nearly all Northern Asia was occupied by grass and tundra dwarf shrub that composed vegetation perhaps having no analogs at present. Woods remained only in refugia along the Pacific coast due to the mild climate formed by oceanic air masses. Climatic fluctuations in Pleistocene were the reasons of repeatation of cold and warm periods, but, in contrast to other regions of Northern Hemisphere, most of this area was never covered by the ice shield, and vegetation had uninterrupted development since tertiary. The cold aridic climate in Asian interior in combination with marine regression caused the formation of land bridges between Asia and America (Beringian land bridge) and between the island arcs and the continent that gave a chance of migration to many drought-tolerant plants (Grichuk 1984) (Fig. 3). Humidity-dependent vegetation could survive Pleistocene aridization in refugia, which could keep moisture due to mountain systems faced to the seas.

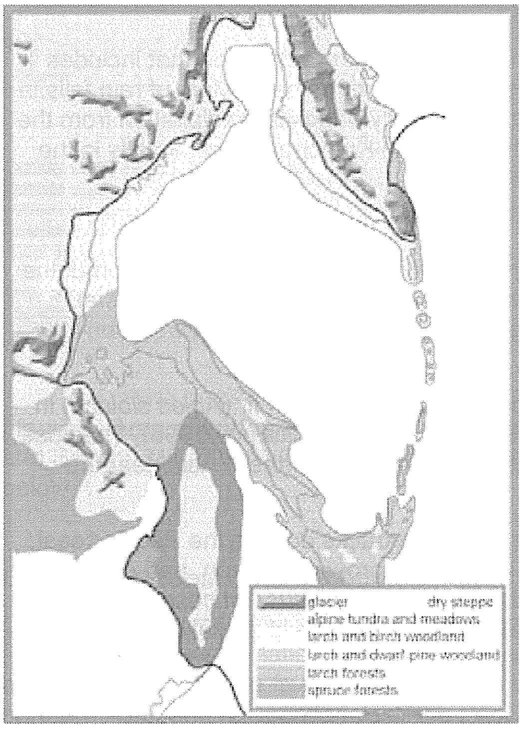


Figure 3. Reconstructed vegetation distribution in the Northeast Asia in Pleistocene Maximum, 18000 BP (simplified from Igarashi 1993). Significant marine regression (sea level droped on more than 100 m) led to increase of the land area and formation of land bridges between big islands. Red line shows modern shoreline. Strong aridization in combination with considerable cooling made the environment in the interior unsuitable for forests. Only the narrow land strip along the sea coast received enough humidity for forest survival. Blue line demonstrates hypotetic area, where forest ecosystems could survive in refugia Pleistocene cooling.

Warming and increasing humidity in Holocene led to expansion of thermophilic and humidity-dependent species from refugia and to contraction of ranges of xeric species invaded the area during Pleistocene aridization. 5000-6000 years BP nemoral vegetation has reached its maximum distrtibution. Perhaps this period was a time of formation of rain forests in their modern appearance. The climatic situation of the last 5000 years is characterized by strong fluctiations in temperature and moisture regimes but has general trend of cooling and drying. Many forest dominants retrieted from the northernmost of their distribution leaving replacing them cold tolerant forests enriched with nemoral species.

Advantage of being wet

The lack of water deficit being favorable for plants feature itself also softens the seasonal climate. Cooler summers and milder winters of humid oceanic climate in conditions of deficit of heat provide favorable conditions for frost intolerant plants, which have their northernmost distribution in the rainforests. Smaller difference between summer and winter temperatures is characteristic to the oceanic regions, where climatic conditions support the development of rainforests. Mild winters prevented formation of permafrost in Pleistocene along the Pacific Coast in the high latitudes. Even in northern areas, where the growing season is too short for trees, and only dwarf alder and stonebirch are able to form stands, we see the vigorous populations of the heat-dependent orchids, lilis and ferns. High humidity creates conservative environmets for many species in times of climatic changes. Local forest of Sakhalin fir on Kamchatka peninsula occurs 2000 km away from the main range, endemic genus *Microbiota* on the Sikhote-Alin Mountains (Fig. 4), localities of species with Japanese distribution isolated on the coast of Asian mainland are good examples of Pleistocene refugia of humidity-dependent species. Late snow melting and abundance of water in early summer, as well as foggy and rainy weather during the growing season decrease probability or prevent wildfires in the area. Because of long history (since Tertiary) of uninterrupted development, closennes to species-rich East-Asian floristic center (Takhtajan 1980) and humidity, plants occupy all possible niches in forest ecosystems that prevent the invasion of weeds.

Fig. 4. Relic and endemic species *Microbiota decussata*. Its distribution is rectricted to the Sikhote-Alin Mts. This is one of few endemic genus of so-called Manchurian floristic province. Photo by H. Homma.

Seasonal Monsoons and Temperate Rainforests

The distribution of rainforests along the Pacific coast of Asia is closely related to the area affected by Asian monsoon. The broadleaved-Korean pine (*Pinus koraiensis*) forest is a zonal vegetation type in the submaritime sector of the northern temperate subzone (Fig. 5). It occurs in the Far East of Russia in the Sikhote Alin Mountains and in northeast China of about 3 millions hectares, but in China these forests were totaly transformed. The broadleaved-Korean pine forests form the lower vegetation belt from sea level up to 800-900 m (Fig. 6). In the southern part of the range they occur up to an elevation of 1100-1200 m (Krestov 2003), coexisting and closely interacting with spruce, larch, and oak forests. The rather wide distribution of this forest type from the seacoast inland, where there is a sharp transition from an oceanic monsoon to a continental climate, have led to marked heterogeneity of vegetation within the zone. Only forests on the eastern slope of Sikhote-Alin faced to the Sea of Japan receive over 1000 mm of precipitation per year. However, the fogs originated from difference in temperatures of air and sea water support the development of epiphytic moss and lichen grouppings on the trunks comparable to humid rainforests of the Pacific Northwest and elsewhere. High humidity also meets the moisture demands of some Japanese species known from few localities on Sikhote-Alin, including *Rhododendron brachycarpum*, *Vaccinium ovalifolium*, *V. praestans*, *Primula jezoana* and others.

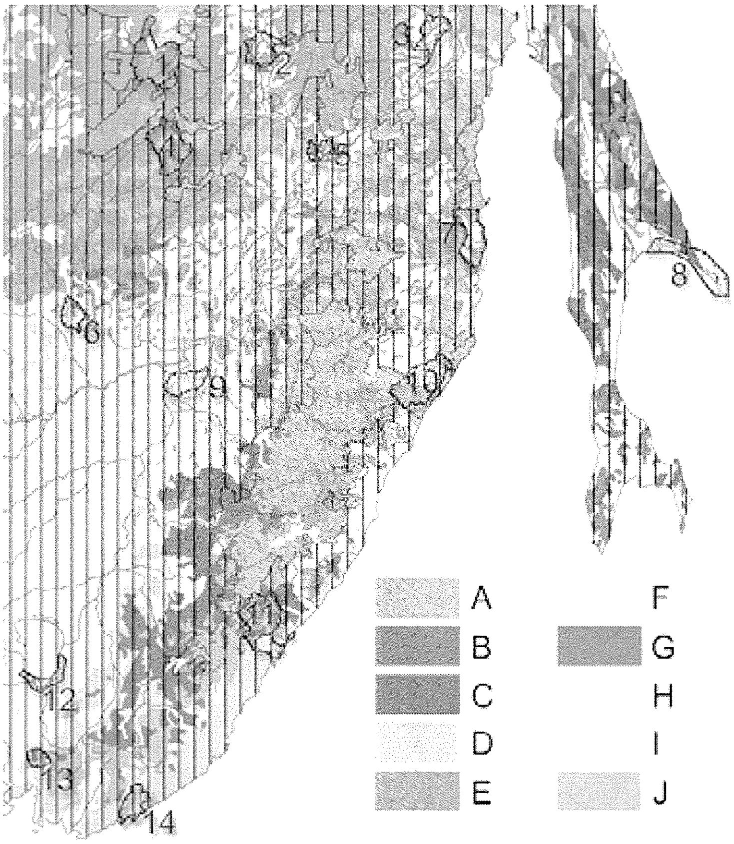


Fig. 5. Distrubution of the Yezo spruce (A), mixed broadleaved-Korean stonepine (B) and Sakhalin fir (C) rainforests in Sikhote-Alin Mountains and Sakhalin island (frame 1 on the figure 1). Other vegetation types: D – secondary broadleaved deciduous forests, E – Cajander larch forests, F – secondary forests of white birch and aspen, G – secondary stonebirch forests, H – wet meadows, I – mesic and dry meadows and croplands, J – alpine vegetation. Patterned areas shows anthropogenically transformed forests, intact forests are unpatterned (simplified from Alsenov et al. 2002). Protected areas: 1 – Bureinskiy nature reserve, 2 – Oldzhikanskiy protected area, 3 – Udylskiy protected area, 4 – Badzhalskiy protected area, 5 – Komsomolskiy nature reserve, 6 – Bastak nature reserve, 7 – Tumninskiy protected area, 8 – Poronayskiy nature reserve, 9 – Khekhtsirskiy nature reserve, 10 – Botchinskiy nature reserve, 11. Sikhote-Alinskiy biosphere nature reserve, 12 – Khankaiskiy nature reserve, 13 – Ussuriyskiy nature reserve, 14 – Lazovskiy nature reserve.

Fig. 6. Mixed broadleaved-Korean pine forests remained on the slopes of Sikhote-Alin Mts. This is the world-richest temperate forests in latitudinal interval from 40 to 50° N maintaining about 2000 humidity-dependent vascular plants. Photo by P. Krestov.

The mixed broadleaved-Korean pine forests have very complicated canopy structure (Fig. 7). The tree layer normally includes three sublayers, formed by species of different growth forms and different life strategies. The dominants in the mixed-forest ecosystems have different growth forms and life strategies. Up to 12 tree species, including Korean stonepine, Manchurian yellow birch (*Betula costata*), Amur linden (*Tilia amurensis*), Manchurian linden (*T. mandshurica*), Manchurian ash (*Fraxinus mandshurica*), Noseleaf ash (*F. rhynchophylla*), Manchurian walnut (*Juglans mandshurica*), Mongolian oak (*Quercus mongolica*), Japanese elm (*Ulmus japonica*), Castor aralia (*Kalopanax septemlobus*), Needle fir (*Abies holophylla*) can be found growing together in the canopy (upper sublayer). Their usual height is 25–35 m, but on rich sites Korean stonepine and Needle fir can reach 45 m, exceeding the height of all other canopy trees and forming a sparse cover above the canopy. An uneven age structure is characteristic of old-growth mixed forests with Korean pine.

Fig. 7. The mixed broadleaved-Korean pine forests have very complicated canopy structure that provides a variety of ecological niches for animals and birds. Photo by P. Krestov.

Despite the high didersity in canopy species, the most important processes in this forest type are controlled by Korean stonepine, the long-living moderately shade-tolerant species. The seeds of Korean stonepine (Fig.

8) are an important source of energy for long food chains that start with highly specialized on the pine seeds small rodents as well as some big representatives of Far Eastern fauna, such as bears and wild boars.

Fig. 8. Korean stonepine is an important source of energy for long food chains that start with highly specialized on the pine seeds small rodents as well as some big representatives of Far Eastern fauna, such as bears and wild boars. Photo by P. Krestov.

A middle tree layer, 12-20 m high, is composed of Mono maple (*Acer mono*), Manchurian maple (*A. mandshuricum*), Manchurian elm (*Ulmus laciniata*), Maximowicz's cherry (*Prunus maximowiczii*), Amur maackia (*Maackia amurensis*), Amur ash (*Sorbus amurensis*), Japanese yew (*Taxus cuspidate*), and Korean whitebeam (*Micromeles alnifolia*). A third tree layer also occurs in almost all undisturbed mixed forests, consisting mainly of Sawa hornbeam (*Carpinus cordata*), Ukurundu maple (*Acer ukurunduense*), Korean maple (*A. pseudosieboldianum*) and Amur tree lilac (Ligustrina amurensis), reaching about 6–10 m in height. All these are shade-tolerant species, but they differ in ecology and growth form (Fig. 9).

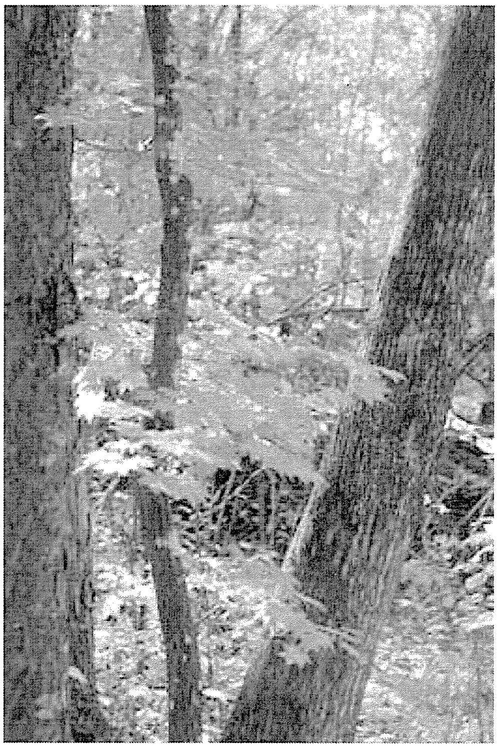


Fig. 9. Korean maple is one of tree species linked to the relict humidity-dependent ecosystems of Eastern Asia. Photo by P. Krestov.

Shrubs are diverse and abundant in the mixed broadleaf-Korean pine forests. Commonly the shrub layer is sparse under the canopy but sometimes very dense in gaps. The shrub layer may merge with other layers due to differences in plant height. If Chrysantha honeysuckle (*Lonicera chrysantha*), Maximowicz's currant (*Ribes maximoviczianum*), and Amur barberry (*Berberis amurensis*) do not exceed 1 m, then Manchurian hazel (*Corylus mandshurica*) and Bearded maple (*Acer barbinerve*) can reach 6–7 m in height. The shrub layer is valuable for sapling development, especially in the early stages of post-disturbance succession.

An herb layer is usually very well developed and characteristic for the mixed forests. Usually different herb species are grouped occupying certain ecological niches. Because of low light levels in the forest understorey, almost all herbs are shade-tolerant, and capable of intensive vegetative reproduction or long-term dormancy. The herbs are quite different in growth form and life strategy; most competitive are the nemoral broad-leaved herbs with leaves oriented horizontally. The average number of species in a phytocenosis may vary between 20 and 100. The total number of herbaceous understorey species in the mixed forests exceeds 600. These forests are major habitat for legendary ginseng (*Panax ginseng*) (Fig. 10-11), the valuable plant in a long history of Asian medicine. Its population is severly destroyed within original range. In Korea and China it is cultivated plant. The last wild population remained in Ussurian taiga.

Fig. 10. Legendary ginseng (*Panax ginseng*) is valuable plant in a long history of Asian medicine. Its population is severly destroyed within original range. In Korea and China it is cultivated plant. The last wild population remained in Ussurian taiga. Photo by.

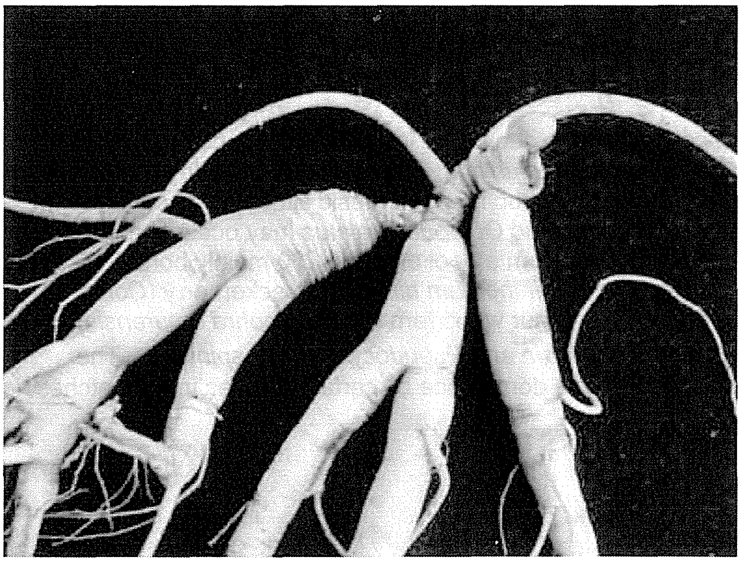


Fig. 11. Roots of ginseng are the subject for crouds of ginseng-hunters during the centures. These roots were cultivated; this is visible from the wide annual increments on the rootnecks. In the wilderness this species grows extremely slowly. Photo by.

A special feature of this type of forest is the presence of woody vines, especially Amur grape (*Vitis amurensis*), Hardy kiwifruit (*Actinidia arguta*), Kolomikta (*A. kolomikta*), Silvervine (*A. polygama*), Magnolia vine (*Schisandra chinensis*), and Oriental staff vine (*Celastrus orbiculata*). A dense cover of mosses or lichens is usually uncommon on the ground, but very diverse on the trunks.

At altitudes of 1100-1200 m in Changbai, 800-900 m in Sikhote Alin and 500-600m on the southern spurs of the Tukuringra-Dzhagdy and Badzhal'skiy ranges, broadleaved-Korean pine forests gradually give way to evergreen conifer fir-spruce forests (Fig. 5) that also receive enough moisture to qualify as "rainforests". The range of the fir-spruce forests extends north to the latitude of 55-57°.N. In the northern temperate zone they constitute the zonal vegetation of the maritime and oceanic sectors of the southern and middle boreal zone of about 15 millions hectares. The amount of precipitation received by fir-spruce forests increases to 1500-1800 mm per year with ~ 30% of this amount falling in winter time.

The main species in the dark-conifer forests is Yezo spruce, forming dense canopies 20–25 m high with trees 50–60 cm in diameter (Fig. 12). Maximum stand height varies from 30 m with 80–85 cm diameters in the north to 37 m in the south. Due to its high shade tolerance, spruce is less dependent on canopy gaps. Horizontal stand structure is commonly random, but because of dense moss cover spruce may regenerate successfully on decomposing fallen logs and stumps that causes formation of small patches within a stand. The lower tree layer contains suppressed or younger trees of spruce with a mix of Manchurian fir (*Abies nephrolepis*). Shorter trees of Amur ash always occur individually in the second or third tree layers.

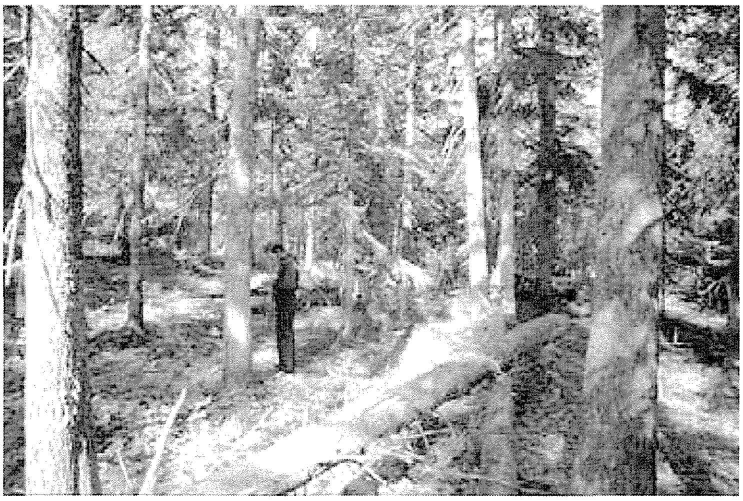


Fig. 12. The Yezo spruce forests in Sikhote-Alin Mountains. Photo by P. Krestov.

The shrub layer usually cannot develop in dark-conifer forests due to the low light levels under the dense canopy. Prickly rose (*Rosa acicularis*), Wingy spindles (*Euonymus macroptera*), Birch spiraea (*Spiraea betulifolia*) and shrubby Ukurundu maple may form a sparse shrub layer on mesic sites. At the contact with the temperate zone, shade-tolerant nemoral shrubs such as relic *Oplopanax elatus* may occur in the spruce forests (Fig. 13). The herb layer may be composed of plants from a pool of about 250 mainly boreal vascular species, including small herbs and dwarf-shrubs May lily (*Maianthemum bifolium*), crackerberry (*Cornus canadensis*), lingonberry (*Vaccinium vitis-idaea*), and ferns Amur wood fern (*Leptorumohra amurensis*), Northern buckler fern (*Dryopteris expansa*), *Diplazium sibiricum* and *Pseudocystopteris spinulosa*. The patchy structure of the herb layer, with clearly distinguishable dominance by certain species in the patches, is a very characteristic feature for spruce forests.

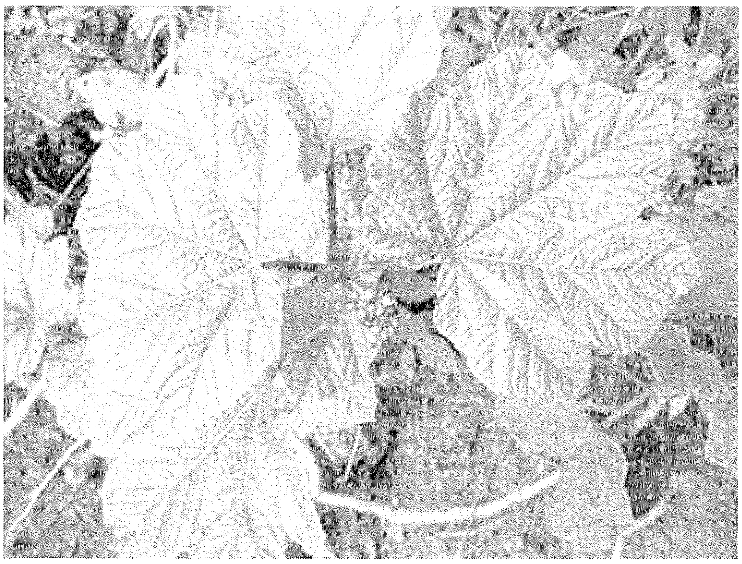


Fig. 13. *Oplopanax elatus* represents genus that occurs in the wettest regions of the temperate zone in Asia and North America. Photo by H. Homma.

Mosses are always present in spruce phytocenoses on mesic and moist sites. On nutrient-poor sites they form a continuous cover with no vascular plants. The most common species on the forest floor are *Hylocomium splendens, Pleurozium schreberi, Ptilium crista-castrensis, Rhytidiadelphus triquetrus, Polytrichum commune*, and *Dicranum majus*.

On Sakhalin (Fig. 5), southern isles of Kuril arc and on the Pacific side of Hokkaido, Sakhalin fir forms pure stands in conditions of cool summers, mild winters and precipitation over 1500 mm with half or more of that falling in winter. Humid fir-spruce forests of the Far East are characterized by presence of many representatives of Japanese flora including the humidity-dependent species that survived severe Pleistocene cooling and aridization due to refugia capable of holding moisture. The species composition of Sakhalin forests is enriched by islanders rugose holly (*Ilex rugosa*), *Skimmia repens*, Evergreen huckleberry (*Vaccinium ovatum*), and pubescent huckleberry (*V. hirtum*), the species of Japanese flora.

Sikhote-Alin forests, also known as 'Ussurian taiga', served as a species-rich refuge during the Pleistocene ice-age that now includes over 100 globaly unique (endemic) species of plants and animals with origins dating back to the Tertiary boreo-nemoral biome (time between extinction of dinosaurs and beginning of the Pleistocene ice-age). Endemics include world's largest cat, Amur tiger (*Panthera tigris atlaica*) (Fig. 14), an isolated and very small population of snow leopard (*Panthera pardus orientalis*) and the last in a world wild population of a famous medicinal plant, ginseng (*Panax ginseng*).

Fig. 14. Tiger's history somewhat repeats the ginseng story: limitless hunting, range fragmentation, decrese of population, urgent protectice efforts, and population stabilization within numbers of 400-500 individuals. This animal became a symbol of Ussurian taiga, the place highlighted in novels of Arseniev and in famous movie of Akira Kurosawa "Dersu Uzala". Photo by V. Yudin.

Humidity catchers in the heart of Eurasia

Southern Siberia is a place where boreal zone contact with temperate steppe (dry grasslands). Zonal vegetation on the plains is represented by steppe under the influence of aridic climate changes to humid broadleaved-Scots pine (*Betula pendula+Populus tremula+Pinus sylvestris*), Siberian fir and Siberian stonepine forests on lower, medium and higher elevations in the mountains of Altai and Sayany (Fig. 15). These mountain systems affected by the Atlantic, dump air masses and receive over 1,500 mm of precipitation nearly evenly distributed seasonally. The conditions of relatively high temperature and high humidity at the isolated area of approximately 11300 km^2, here in the heart of Eurasia led to formation of specific humid forest types characterized by boreal dominants, well-developed layers of shrubs and tall herbs reaching a height of 1.5-2 (4) m.

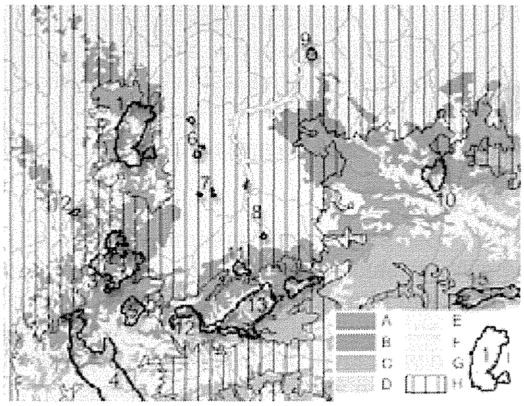


Fig. 15. Distrubution of Siberian fir (A) and subalpine Siberian stonepine (B) rainforests in Altai and Sayany Alin Mountains (frame 2 on the figure 1). Other vegetation types: C – a complex of dry Sinerian larch and Siberian stonepine forests, D – Scots pine forests, E – secondary forests of white birch and aspen, F – alpine vegetation, G – dry meadows and steppe, H – antropogenically transformed vegetation (simplified from Alsenov et al. 2002), I – protected areas (1 – Kuznetskiy Alatau nature reserve, 2 – Lipoviy Ostrov (nature monument for protection of site of the relic Tilia cordata ecosystem), 3 – Shorskiy national park, 4 – Altayskiy nature reserve, 5 – Khakasskiy nature reserve (several clusters), 6 – Shushenskiy Bor national park, 7 –

Ubsunurskaya Kotlovina nature reserve, 8 – Sayano-Shushenskiy nature reserve, 9 – Ergaki national park, 10 – Stolby nature reserve, 11 – Tofalarskiy protected area, 12 – Azas nature reserve).

Two basic forest types, Siberian fir (Fig. 16) and subalpine Siberian stonepine (Fig. 17) representing upper vertical forest zones on the windward slopes of mountain massifs fit to the concept of rainforest here in condition of as high as it is only possibe humidity at higher elevation of Sayany and Altai mountain systems. The humid mountain areas among very dry region occupied by steppe keep many relic humidity dependent species.

Fig. 16. Siberian fir rainforests of Sayany. At the front there are 2 major dominants: Siberian pine and Siberian fir. Photo by P. Krestov.

Fig. 17. Subalpine Siberian stonepine forests occur in condition of as high as it is only possibe humidity at higher elevation of Sayany and Altai mountain systems. The humid mountain areas among very dry region occupied by steppe keep many relic humidity dependent species. Photo by P. Krestov.

Siberian fir forms pure stands in the middle elevations in conditions of high air humidity (Fig. 18). In the lower part of the belt a mix of Siberian stone pine is characteristic (Fig. 19.), however the stands in that case have patchy structure with stonepine groupped on elevated and well drained microsites. The tree layer is very simple and usually includes two storeys represented by the same species in different age or viability states. The presence of Sorbus sibirica is characteristic to the second storey.

Fig. 18. Siberian fir rainforests from inside. Branches of fir is coated by lichen *Usnea longissima*. Photo by N. Stepanov.

Fig. 19. Mixed pine-fir forest from inside. Photo by P. Krestov.

Shrub layer is puurly developed, while a herb layer is very dense and diverse. In addition to the circumboreal species, these forests have a very high proportion of nemoral species in the understorey (Fig. 20). Most of nemoral species (*Actaea spicata*, *Asarum europaeum*, *Brachypodium sylvaticum*, *Brunnera sibirica*, *Carex sylvatica*, *Chrysosplenium ovalifolium*, *Daphne mesereum, Dentaria sibirica, Festuca altissima*, *Frangula alnus*, *Sanicula europaea* and *Stachys sylvatica*) belongs to European and / or Mediterranian flora and occur at the eastern edge of their distribution. However, some Tertiary relict species (*Anemone baicalense*, *Menispermum dahuricum* and *Waldsteinia ternata*) are of East Asian origin. In addition, there are about 40 representatives of nemoral mosses and lichens.

The ancestral vegetation of these forest types were heavily suppressed by climatic disasters in Pleistocene and could not maintain their species composition or structural features until the present. However, the mountains of southern Siberia became a peculiar "Noah's ark" for many mesic herbs and shrubs that probably constituted different community types before Pleistocene coolings and aridizations (Stepanov 1999). Perhaps, ecosystems of this type served in Pleistocene as refuge for Siberian linden that at present occurs in drier climate. Modern forest structure as well as species composition of southern Siberia rainforests look somewhat eclectic and include plants characteristic to subalpine meadows, nemoral and boreal forests (Ermakov 2003). The modern humid and mild climate corresponds to northern temperate type these forests keep their "boreal" appearance due to long isolation from distribution areas of potential nemoral dominants.

Fig. 20. One of most notisable representative of humidity-dependent nemoral relict species in Sayany Mts., Daphne mesereum. Photo by P. Krestov.

Subalpine Siberian stonepine forests have short (6-20 m) and relatively sparse monodominant tree layer, poorly developed shrub layer that includes Altai honeysuckle (*Lonicera altaica*) and sometimes Siberian juniper (*Juniperus sibirica*) and single-flower cotoneaster (*Cotoneaster uniflorus*). Herb layer is dense and composed of medium and tall forbs *Aegopodium alpestre*, *Aconitum septemtrionale, Veratrum lobelianum, grasses Anthoxanthum alpinum, Calamagrostis langsdorffii, Poa sibirica*, and small herbs Viola biflora, Stellaria bungeana and *Cruciata krylovii*. Most of moss diversity is concentrated in the gaps of herb layer (dominant species are *Hylocomium splendense, Rhytidiadelphus triquetrus, Pleurozium schreberi*) and on the trunks and branches of Siberian stonepine.

If water is frozen most of year

Kamchatka lies at the northeast edge of Asia, at 51–60°N and 156–163°E. The peninsula is constituted by two main mountain chains, the Sredinniy (middle) and Vostochniy (eastern). The Sredinniy range is the main mountain system of Kamchatka and extends about 1000 km from north to south. The axial part of the range is a zone of Quaternary volcanism that was glaciated in the Pleistocene. The Vostochniy range unites a system of small ranges dissected by a dense river network. The most seismically and volcanically active part of Kamchatka lies along the eastern slope and near the northern end of the Vostochniy range (Fig. 21). The climate of Kamchatka is humid and moderately cold, with a humid snowy winter and short cold summer. The oceanic coastal climate results from cyclones originating in the northern Pacific Ocean and has Betula ermanii as the zonal vegetation. The cyclones bring damp Pacific air and produce high precipitation in the Betula ermanii areas, ranging from 900 mm to 1400 mm per year. The prevalence of cloudy weather in summer causes relatively low mean summer temperatures, ranging from 10°C to 13°C, with maximum in August. Precipitation is distributed nearly equally throughout the year. Maximum snow depth reaches 120–170 cm.

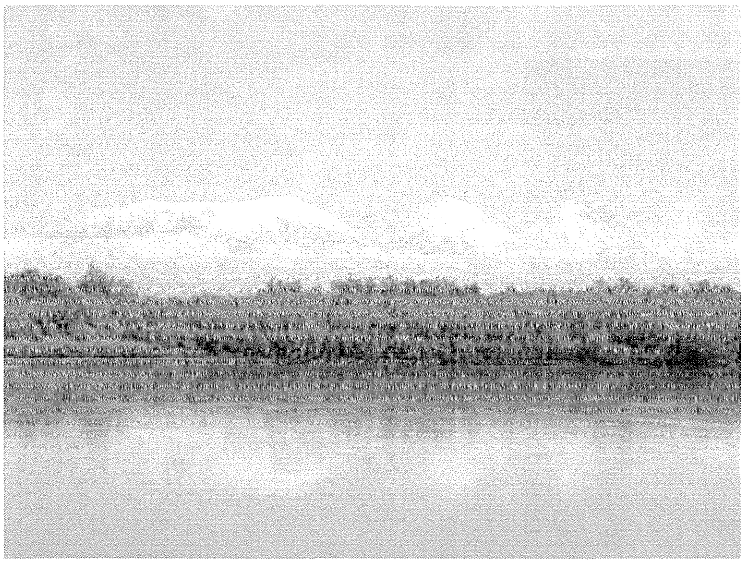


Fig. 21. Beauties of Kamchatka: snowed volcanoes in midsummer. Snow is the major factor determining development of vegetation in this part of Northern Asia. Photo by P. Krestov.

Forests of Ermann's stone birch characterize the maritime and suboceanic regions of boreal northeast Asia. Over its whole range stone birch forms well developed vegetation belts in mountains influenced by oceanic air masses. The elevational limit of the *Betula ermanii* belt varies with latitude. In submaritime areas on the mainland, this birch belt is well-developed in the south but disappears northward, occurring at 1800–2000 m on the Changbai, 1200-1800 m in the Sikhote-Alin (Krestov 2003). In the Magadan area, stonebirch forms community fragments on the seacoast. In maritime and suboceanic climates, stone birch forms forest belts at 1400-1600 m on Hokkaido, Japan. Ermann's stonebirch extends north through the Kuril Islands to Urup, where it forms stands from sea level to 400 m; it does not occur in the northern Kurils. About 70% of all stonebirch forest is in Kamchatka (Fig. 22), where it occurs as an extensive horizontal vegetation zone, over a wide range of ecologically different sites (Krestov 2003). The total area of stone birch forests is estimated as 0.7 millions hectares. *Betula ermanii* does not occur in wetlands or on permafrost, but its distribution does depend, among other factors, on snow depth and timing of snowmelt (length of snow-free period).

Fig. 22. Distrubution of Siberian dwarf pine (A), Yezo spruce (B), Ermann's stonebirch (C) rainforests and dwarf alder thickets (D) in Kamchatka peninsula (frame 3 on the figure 1). Other vegetation types: F – riparian willow forests, G – secondary forests of white birch and aspen, H – a complex of Siberian dwarf pine and tundra, I – a complex of Cajander's larch forests and tundra, J – Cajander's larch forests, K – wet meadows, L – alpine vegetation, M – antropogenically transformed vegetation (simplified from Alsenov et al. 2002), N – protected areas (1 – Kronotskiy nature reserve, 2 – Yuzhno-Kamchatskiy protected area).

Betula ermanii has very wide, low crowns with side branches developed at the same angle as the axial stem. When the terminal bud of young trees reaches outside the snow cover, the axial shoot is damaged, perhaps killed by snow abrasion, and is replaced by the shoot from the lateral bud. This is the main reason for the crooked stems in many stands (Fig. 23). The late snowmelt and short snow-free period limits potential conifer competitors. The maximum size of trees is 1.3–1.8 m in diameter and 15–25 m in height. The recorded maximum age is 500 years. *Betula ermanii* dominates the stands, forming a well-developed canopy with a cover of 70-80%. *Alnus fruticosa*, *Pinus pumila* and *Sorbus sambucifolia* may form the tall-shrub layer in stone birch stands. The herb layer varies widely depending on local site ecology and includes several strata. Most common in the tallest stratum, reaching 2 m, is *Angelica ursina* (in the south and west), *Heracleum lanatum, Senecio cannabifolius, Cacalia hastata, Cirsium kamtschaticum, Veratrum alpestre, Aconitum maximum, Urtica platyphylla* and *Filipendula camtschatica*. This group is usually called 'Kamchatkan tall herbs'. Because the whole *Betula ermanii* forest area is in a humid climate, and thus has well-developed herb layers, a moss-lichen layer on the ground is not abundant/. However, the mosses anad lichens are very diverse on the birch stems.

Fig. 23. Main vegetation on Kamchatka is the forests of Ermann's birch, whose twisted trunks remind the masterpiece of a Japanese gardener. Creator of this beauty on Kamchatka is snow. Deep snow and its late melting prevent regeneration of conifer trees in such conditions. Another heroe in this picture is Siberian dwarfpine. Photo by P. Krestov.

The Siberian dwarf-pine (*Pinus pumila*) is one of the most unusual and interesting woody species in its appearance and adaptations (Fig. 24). It occurs widely in northeastern Asia, forming a vertical vegetation belt in mountain systems, but as zonal vegetation type it occurs across suboceanic sectors of the subarctic zone in conditions of hyperhumid climate with heavy snow covering the ground almost 8 months per year (Fig. 25). Total area of Siberian dwarf-pine is about 0.75 millions hectares (Anonymous 1990). The territory where *Pinus pumila* forms monodominant communities on zonal sites stretches approximately from 60°N to 67°N, within the intensively dissected mountainous terrain of northeasternmost Asia. The ecoform of Siberian dwarf pine seems not to have an analog among other tree or shrub species. Adaptation to severe climatic conditions with deep snow cover results in a very specific crown architecture and seasonal dynamics. Many authors include the growth form of *Pinus pumila* in the class of dwarf trees. Under favorable conditions (well developed soil profile), *Pinus pumila* grows as a dwarf tree with one main stem lying on the ground and well-developed upwardly growing branches, elevated to about 6 m in the summer. In northern Sakhalin the largest basal diameters measured were 32 cm, stem length 14 m, and branch height 4 m; on the Shantar Islands the largest recorded basal diameter was 40 cm.

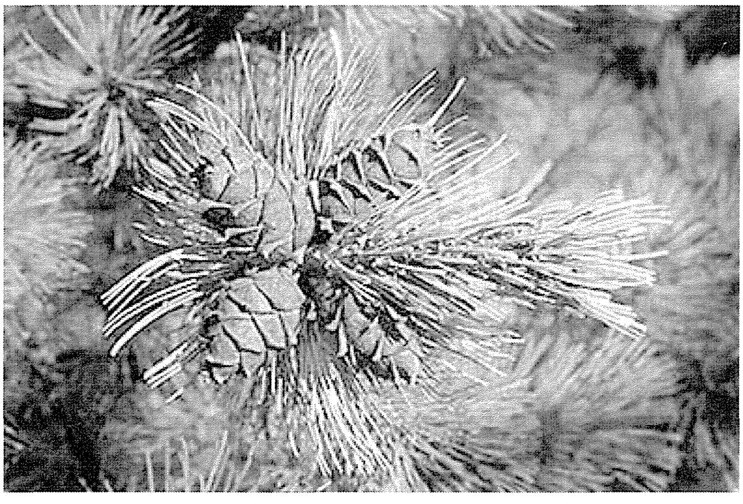


Fig. 24. Siberian dwarf-pine. Photo by P. Krestov.

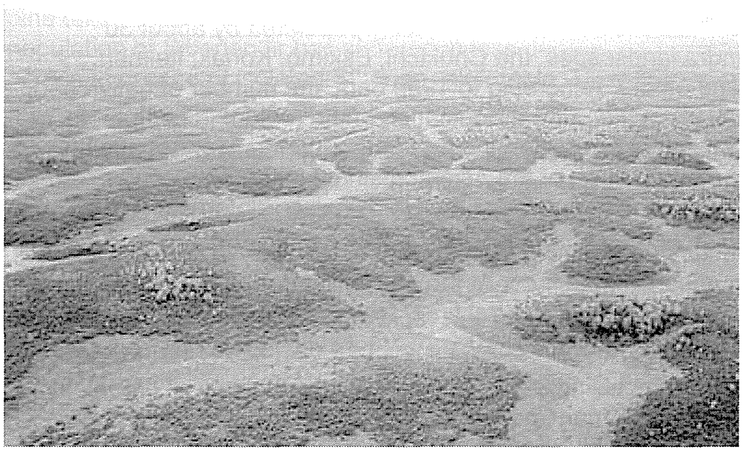


Fig. 25. Northern Kamchatka and Siberian dwarf-pine zone. This pattern was drawn by snow: shallow snow and its earlier melting led to the formation of small patches of Ermann birch on the sunniest sites; deepper snow - Siberian dwarf pine; and even deepper snow - tall herb meadows. Photo by P. Krestov.

Dwarf alder (*Alnus fruticosa*) thickets increase in this zone towards the Pacific Ocean and appear to be the dominant vegetation type on zonal sites on the easternmost Kamchatka (Fig. 22: D) and the northern Kurils on the area of about 0.2 million hectares (Fig. 26). This vegetation type occurs on saturated sites throughout the Beringian Woodland area and forms pure stands on zonal sites in easternmost Koryakia, southeastern Kamchatka, and on the northern Kuril Islands in conditions of subarctic suboceanic climate characterized by very low amount of heat, high (over 1500 mm) precipitation most of which falls in winter, and very low insolation in summer, due to fog and cloudiness (total hours <1000–1500 per year).

Fig. 26. If snow is extremely deep and summer is cool, the only shrub that can survive is dwarf alder (Alnus fruticosa). This picture was made in the warmest for Northern Kuril Islands month August. Summer temperature is not high enough to melt the snow accuimulated during long winter. Photo by P. Krestov.

Human impact

People on the territory of Northern Asia according to different estimations appeared 400-800 thousands years BP; however, they became a significant forest distrurbance with the beginning of fire use about 40 thousands years BP. On the territory of southern Siberia several ancient cattle-raising civilizations (Scythian and Hunn - 800-200 years BC, Turkish – 2000-1000 years BP, Mongolian – 1000-400 years BP and Dzhungarian 400-300 years BP) changed forest conditions. Grazing in combination with wood use for heating caused the first deforestation in the mountains of Altai and Sayany. However, the first Russians that arrive in this territory in 17th centurs noticed ancient forests.

The Far Eastern part of Northern Asia before Russians arrived was sparsely populated by about 30 indigenous tribes related to the forest and tundra landscapes: the Chuktchi, Eskimo, Koriak, Itelmen, Aleutian, Even, Evenk, Nanai, Ulchi, Nivkh, and others. According to 1959 data, the number of native people was estimated at 50,000, which was less than 1% of the current population of the region. In contrast to southern Siberia, the Far Eastern people represented forest-dependent tribes with poorly or not at all developed agriculture. Russians reached the eastern edge of the Asian continent in the 17th century. Since the 19th century industial forestry became the major disturbance for the North Asian rainforests.

Nowadays, the most important disturbance factors determining the pathway of recovery in temperate and boreal rainforests are wood harvesting and human-initiated fires. At the background of antropogenically transformed areas, the natural disturbances, such as winds, natural fires, forest declines by insects became insignificant.

The maps of potential vegetation (Fig. 1) and bioclimatic indices assume a wide distribution of broadleaved-Korean pine forests on edaphically suitable sites in the maritime sector of the northern temperate zone. However, the area of this vegetation type has considerably decreased in China and adjacent parts of Russia west of the Sikhote Alin Mountains. Most authors ascribe this decrease to human activity by the Dzhurzhen population between 500 and 800 AD. During that period, forests were decreasing in area due to clearing for agriculture. Since then the area has remained relatively densely populated, and regular fires have supported the development of vegetation without conifers. In the beginning of the 19th century, the basin of the Ussuri River was settled by Russians. The first forest records appeared in the second half of that century, but more extensive forest records from China and Russia date from the time when local and international forest companies started to operate at the beginning of the 20th century. According to records from the 1890s, the broadleaved–Korean pine forests on Sikhote Alin covered an area of about 65000 km^2 and Abies–Picea forests about 30000 km^2. Nowadays the areas have decreased by 33000 km^2 and 4000 km^2, or 51 and 14 % respectively.

The major reasons for the decrease of forest area are extensive logging and fires. The area formerly covered with broadleaved–Korean pine forests is now occupied by secondary Betula platyphylla and Larix cajanderi forests (3500 km^2) formed mainly after logging and/or single fires, secondary Quercus mongolica forests (12000 km^2) formed after logging and regularly repeated fires, especially around settlements, and by agricultural land (about 15000 km^2). The area of Abies–Picea forests decreased only by 4000 km^2; they were replaced mostly by secondary forests of Betula platyphylla and Larix dahurica. The relatively small decrease may be explained by the lack of land suitable for agricultural use and the sparse human population. Decrease in forest area however, does not reflect the decline of the quality of forests as a consequence of the disturbance regimes and the features of post-disturbance succession in different vegetation types.Over seventeen years, changes in forest cover in Primorskiy Krai (Anonymous, 1990) were:

Vegetation type	1966	1983	change (%)
scrub	25.1	38.1	+51.8
oak forests	2301.2	3126.8	+35.8
other broadleaved forests	2123.6	1733.4	−18.4
larch forests	1090.1	1136.7	+4.3
broadleaved Korean-pine rainforests	2439.4	2181.9	−10.6
Yezo spruce rainforests	13624.4	13686.3	+0.4
Yotal forest area	116784.2	118869.9	+1.8

The potential forest area in the northeast of China extends north from the latitude of 40°45'N and covers the provinces of Heilongjiang, Jilin and Liaoning. According to FAO data (Anonymous, 1982), the percentage of forest cover in these provinces is at present 30−40%, 23−30% and 10−20%, respectively. Large areas of natural forest in northeastern China are to be found only in inaccessible high-elevation regions on the Lesser Hingan and Changbai Shan mountain ranges, while the plains are intensively cultivated and densely populated.

Most of the rainforests of southern Siberia has been logged in 1960-70th. The industrial logging led to nearly elimination of significant populations of Siberian stonepine because of its valuable timber. Regeneration of pine takes very long time due to inhibiting effect of tall herb cover in ecosystems of rainforests. The population of Siberian fir has suffered in less degree, and extensive tracks of this forest type can be found across the range of isolated Siberian rainforests. They form a unique ecosystem that is very sensitive to the equilibrium between the air humidity and changing temperature.

Situation in Kamchatka remains much better with Ermann's stonebirch due to the low value of timber and same much worth with the isolated tracks of the relict Yezo spruce forests in central Kamchatka that had been logged in 1970s. The major factor of forest survival there is very high humidity that prevents forest fire. The major losses from fires are in the formation of Siberian dwarf pine around the settlements.

Two centuries of industrial forestry has reduced rainforests by about 60 %. However the rainforests of Northern Asia remain up to now most well conserved among the rainforests of the world. The coniferous forests of Korean stonepine and Yezo spruce sufferred more than others because of the high value of timber. Despite the big losses of forests, north Asia stills has extensive reinforests with part of them being at different stage of post-logging and post-fire recovery.

Conservation issues

Conservation policy in relation to the rainforests usualy chases the forest industry, in accordance with a principle first cut then protect. Most of nature protection areas were established on formerly logged areas, and it did work for most successful recovery of the rainforests after disturbances. The most effective way for ecosystem conservation in Russia is the nature reserve, the territory with restricted admittance and fully prohibited antropogenic activity. However thare are exclusions, thank to which we still have opportunities to know how the oldgrowth rainforest may look like. Below is the list of the nature reserves with references on figures 5, 15 and 22, their establishment year, area and the type rainforest protected coded as As – Siberian fir, Ps – Siberian stonepine, Pk – Korean stonepine, Pj – Yezo spruce, Pp – Siberian dwarf pine, Af – Dwarf alder, Be – Ermann's stonebirch.

Nature reserve name	Year	Area (he.)	Rainforest type	State
Altayskiy (Fig. 15: 4)	1967	881238	As, Ps	primeval
Azas (Fig. 15: 12)	1985	300390	No rainforests	–
Ubsunurskaya Kotl. (Fig. 15: 7)	1993	39640	Ps	primeval
Khakasskiy (Fig. 15: 5)	1999	267483	No rainforests	–
Bastak (Fig. 5: 6)	1997	91375	Pk, Pj	logged
Koryakskiy (Fig. 22: 1)	1995	327106	Pp, Af	primeval
Sayano-Shushenskiy (Fig. 15:8)	1976	390368	No rainforests	–
Stolby (Fig. 15: 10)	1925	47154	As	logged / burned
Lazovskiy (Fig. 5: 14)	1957	120989	Pk	logged / burned
Sikhote-Alinskiy (Fig. 5: 11)	1935	401428	Pk, Pj	primeval
Ussuriyskiy (Fig. 5: 13)	1932	40432	Pk, Pj	primeval
Khankaiskiy (Fig. 5: 12)	1990	43679	No rainforests	–
Bolonskiy (Fig. 5)	1997	103600	No rainforests	–
Khekhtsirskiy (Fig. 5: 9)	1963	45439	Pk, Pj	logged / burned
Botchinskiy (Fig. 5: 10)	1994	267380	Pj	primeval
Bureinskiy (Fig. 5: 1)	1987	358444	Pj	logged / burned
Komsomolskiy (Fig. 5: 5)	1963	64278	Pj	logged / burned
Kronotskiy (Fig. 22: 2)	1967	1142134	Be, Af, Pp	primeval
Kuznetskiy Alatau (Fig. 15: 1)	1989	412900	Ps, As	primeval
Poronayskiy (Fig. 5: 8)	1988	56695	No rainforests	–

The reserves created before the WWII contributed their best into the rainforest conservation. However at time of war their forests suffered from the irregular logging for firewood. From the other hand, even reserves created on the formerly logged areas still may have intact rainforests on the inaccessible for machines sites, such as steep slopes. The establishment of reserve in the areas after selective cutting leads to the fastest regeneration of all forest components.

In Russia, other forms of nature protection are practiced. Some areas, where one of the nature components becomes somewhat vulnerable, can be given by special status of protected area (known as zakaznik, from ancient Russian 'to prohibit') with restriction for some kinds of nature use, for example different kinds of hunting, logging, mining etc. The areas of traditional forest use in the Sikhote-Alin Mountains became very effective tool for keeping largest massifs of the broadleaved-Korean pine rainforests in Bikin River, tributary of Ussuri (Amur River basin). These forests are permitted to indigenous tribe, the Udege people for hunting. The intension of hunters to keep high population of game species corresponds to very basic idea of all conservation strategies that is the maintenance of high diversity of ecological niches.

Since the establishment of forest industry in southern Siberia and the Russian Far East there were several state lows regulating forest use in different conditions. Due to these regulations, intact forests remained even in logged areas along the rivers (width of water protective strip depends on the size of river), on the slopes steeper than 35° and along the mountain ridges. To avoid disappearance of mixed broadleaved-Korean pine forests, it 1990s, the logging in Korean pine dominated forests was prohibited by low that helped to keep several important massifs of rainforests in Sikhote-Alin mountains.

The world-wide conservation programs on saving rare animals turn to the protection of their habitats. The Amur tiger (Panthera tigris altaica) and snow leopard (Panthera pardus orientalis) represent the tops of the food pyramids of the Korean stonepine rainforest ecosystems and appeared to be most influenced by forest area contraction due to the loss of feeding territory and of a number of key prey species. Only ~ 450 tigers and 29 leopards remain in Sikhote-Alin Mountains, numbers believed too low to sustain the species. Strict protection by low and numerous conservation programs allowed slowed the population declines. The major task now is to avoid fragmentation of habitats that include protection of intact Ussuri taiga.

Literature Cited

Aksenov D., Dobrynin D., Dubinin M. et al. (eds.) 2002. Atlas of Russia's intact forest landscapes. Biodiversity Conservation center, Moscow, 185 pp.

Anonymous. 1982. Forestry in China. FAO Forestry paper 35. Rome, FAO UN. 308 pp.

Anonymous. 1990. Reference Book for the taxation of forests of [Russian] Far East. [Spravochnik dlya taksatsii lesov Dalnego Vostoka]. Dal'NIILKh, Khabarovsk, 526 pp. (in Russian).

Ermakov N.B. 2003. Raznoobrazie boreal'noi rastitel'nosti severnoi Asii. Kontinental'nie gemiboreal'nie lesa, klassifikatsiya i ordinatsiya (Diversity of boreal begetation of Northern Asia. Hemiboreal forests. Classification and ordination). Izd-vo SO RAN, Novosibirsk. (In Russian).

Grichuk, V.P. 1984. Late Pleistocene Vegetation History. In: Anonymous. Late Quaternary environments of Soviet Union, pp. 155-178. Univ. Minnesota Press, Minneapolis.

Igarashi, Y., 1993. History of environmental change in Hokkaido from the viewpoint of Palynological research. In: S. Higashi, A. Osawa and K. Kanagawa (Editors), Biodiversity and Ecology in the Northernmost Japan. Hokkaido University Press, Sapporo, pp. 1−19.

Krestov, P.V., 2003. Forest vegetation of Easternmost Russia (Russian Far East). In: Forest Vegetation of Northeast Asia. Kluwer, Dordrecht, pp. 91−179.

Lavrenko E.M., Karamysheva Z.V., Nikulina R.I. 1991. Steppes of Eurasia. Nauka, Leningrad. 146 pp.

Nakamura Y., Krestov P.V. 2005. Coniferous forests of the temperate zone of Asia // F. Andersson (ed.) Coniferous forests (Ecosystems of the World, 6). Elsevier Academic Press, NY, Paris, London, Brussels et al. P. 165-220.

Nazimova, D.I., Polikarpov, N.P. (1996). Forest zones of Siberia as determined by climatic zones and their possible transformations under global change (in Russian). Sylva Fennica 30 (2-3): 201-208.

Nazimova D.I., Ponomarev E.I., Stepanov N.V., Fedotova E.V. (2005) Chern dark-coniferous forests in the South Krasnoyarsk region and the problems their mapping (in Russian) Forestry 1, 12-18.

Stepanov N.V. (1999) Floristic peculiarities of vascular plants in the North-East part of the West Sayan (in Russian). Botany Journal 84 (5): 95-101.

Takhtajan A.L. 1986. Floristic regions of the world. Berkeley, LA. 320 p.

Vasiliev, V.N., 1958. Proiskhozhdeniye flory i rastitelnosti Dalnego Vostoka i Vostochnoy Sibiri [Origin of flora and vegetation of Far East and Eastern Siberia]. In: Anonymous (Editor), Materialy po Istorii Flory i

Rastitelnosti SSSR [Materials on the History and Flora of the USSR], Vol. 3. Izdatel'stvo Akademii Nauk SSSR, Moscow, pp. 361–457 (in Russian, with English summary).

b. Temperate zone

1) *Quercus liaotungensis* forest in China

Hai-Mei You (*Institute of City and Environment, Xuzhou Normal University, Shanghai Road 29, Tong Shan County, Xuzhou City, Jiangsu Province, 221116, China*)
Kazue Fujiwara & Qian Tang (*Institute of Environmental Science and Technology, Yokohama National University, Tokiwadai 79-7, Hodogaya-Ku, Yokohama City, Kanagawa Prefecture, 240-8501, Japan)*

The deciduous oak forests dominated by *Quercus* spp. are not only significant vegetation types in Northeast Asia (including the continental areas, the Korean Peninsula, and the Japanese Archipelago), but are also the typical type of deciduous broad-leaved forest in China. There are nine main types of deciduous oak forest occurring in different zones and elevations in China, namely *Quercus mongolica*, *Q. liaotungensis*, *Q. serrata* var. *brevipetiolata*, *Q. aliena*, *Q. aliena* var. *acuteserrata*, *Q. dentata*, *Q. acutissima*, *Q. baronii* (hemi-evergreen) and *Q. variabilis* (Wu et al 1995). *Quercus liaotungensis* forest is an important type of deciduous oak forest in the warm-temperature zone (in the Chinese sense), occurring mainly in northeastern China and north China, confined to hills and mountains in Liaoning, Hebei, Shanxi, Shaanxi, Henan, Gansu and Beijing, and extending into the Korean Peninsula (Fig.1). *Quercus liaotungensis* forests also usually occur around the five big mountain ranges in these regions: the Da Xinggan Ling, the Yinshan, the Taihang Mountains, the Yanshan, and the Qingling (shan = mountain range) (Fig. 2).

From 2001 to 2007, field study was carried out according to the Braun-Blanquet (1964) methodology (see Fujiwara 1987), surveying and collecting 213 relevés of *Quercus liaotungesis* forest stands in China. From the relevés of *Quercus liaotungesis* forest stands obtained, the communities of *Quercus liaotungensis* forests were summarized into one class, 2 orders, 4alliances, 3 suballiances and 13 communities (Table 1).

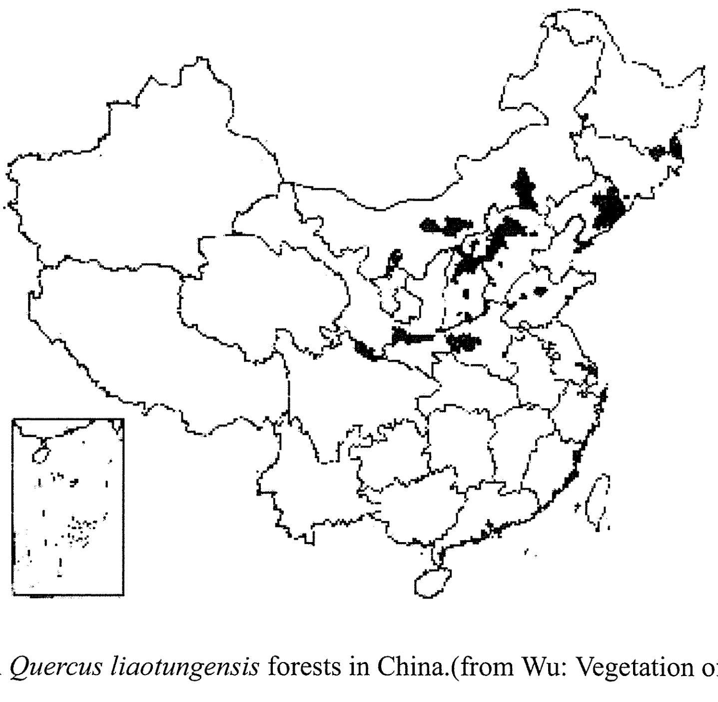


Fig.1 Distribution *Quercus liaotungensis* forests in China.(from Wu: Vegetation of China)

As a type of deciduous broad-leaved forest in Northeast Asia, the species composing the *Quercus liaotungensis* forests show great similarities to those of other deciduous forests (i.e. beech forests and oak forests). Common species of these deciduous forests are *Carex lanceolata*, *Polygonatum odoratum*, *Dioscorea nipponica*, *Vicia unijuga*, *Aster ageratoides*, *Deyeuxia arundinacea*, *Rubia cordifolia*, *Lespedeza bicolor*, *Ulmus macrocarpa*, *Acer mono*, *Euonymus alatus*, *Malus baccata*, *Anemone tomentosa*, *Pinus tabulaeformis*, *Celastrus orbiculatus*, *Fragaria orientalis*, *Berberis amurensis*, *Leibnitzia anandria*, *Acer ginnala*, *Vitis amurensis* and *Convallaria majalis*. The actual vegetation of deciduous oak forests, however, has been destroyed almost completely by human activity; *Quercus liaotungensis* forests were influenced less since they tend to occur at higher altitude than the other oak forests. The habitats and species composing *Quercus liaotungensis* forests are significantly different from those of the other deciduous forests. Usually, *Qu*ercus *liaotungensis* forests (i.e. the Quercetea liaotungensis) are characterized by species such as *Spiraea pubescens / hirsuta*, *Patrinia scabiosaefolia / heterophylla*, *Populus davidiana*, *Ostryopsis davidiana*, *Rosa xanthina*, *Prunus sibiricus*, *Adenophora potaninii*, *Phlomis umbrosa*, *Viola dissecta*, *Betula platyphylla*, *Malus baccata*, *Artemisia mongolica*, *Artemisia annua*, *Ulmus macrocarpa*, and *Atractylodes lancea.*

There are two major types (orders) and four subtypes (alliances) of actual *Quercus liaotungesis* forest in China, which occur in four different regions and are closely related to bioclimatic conditions such as temperature and precipitation (Fig. 3).

The first type (alliance) is the *Paeonia lactiflora-Quercus liaotungensis* forest (i.e. the *Paeonio lactiflora-Quercetus liaotungensis* comm..unity), which occurs on the northeastern Mongolian

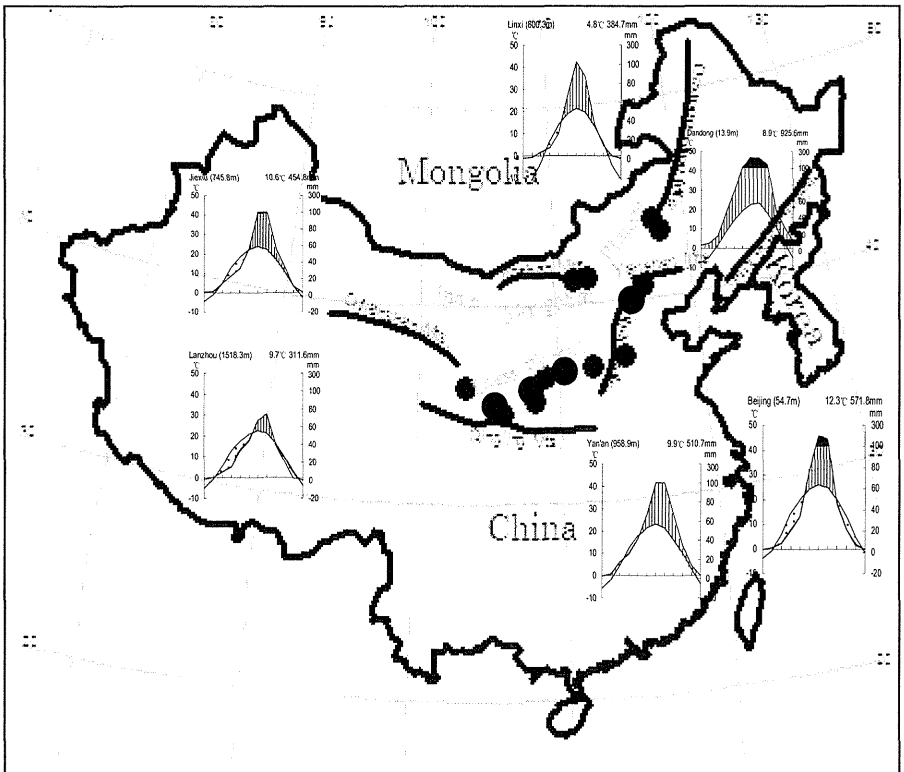


Fig. 2 Study-area locations and Climate diagrams of six nearby meteorological stations.

Plateau. Some of the stands have experienced interference by grazing or cutting, but there are generally three to four structural layers. The canopy has a height of 3m to 13m, with cover values ranging from 10% to 90%. These forests usually occur on thinner, drier soils derived from granite, and grasses form a dense understorey. The diagnostic species are *Paeonia lactiflora*, *Artemisia sacrorum*, *Silene repens*, *Euphorbia esula*, *Geranium sibiricum*, *Achnatherum sibiricum*, *Potentilla fragarioides*, *Adenophora stenanthina*, *Galium verum*, *Carex humilis*, *Hypericum attenuatum*, and *Valeriana alternifolia*.

The second type (alliance) is the *Deutzia parviflora-Quercus liaotungensis* forest (i.e. the Deutzio parviflora-Quercetion liaotungensis all. Prov.), which occurs in the Ji-Liao Mountains (including hills and mountains in northern and western Hebei, in Beijing, and extending to western Liaoning). The stratification of these forests is well developed and usually reveals four layers. The canopy is closed and attains cover values ranging from 65% to 85%, with a height of 8m to 14m. The habitats are usually dry, shallow, nutrient-poor brown forest soils derived from limestone. The community is characterized by *Syringa pekinensis*, *Deutzia parviflora*, *Cornus alba*, *Abelia biflora*, *Clematis kirilowii*, *Saussurea nivea*, *Fraxinus rhynchophylla*, *Spiraea trilobata*, *Synurus deltoides*, *Adenophora divaricata*, *Calamagrostis epigeios*, and *Carpinus turczaninowii* var. *Stipulata.*

The third and forth type (alliances) are summalized into *Acer ginnala-Quercus liaotungensis* forest (i.e. the Acero ginnalae- Quercetalia liaotungensis), which occurs on the Jin-Shaan Loess Plateau (covering most parts of Shanxi, Shaanxi and Gansu). The character and differential species are *Elaeagnus umbellata*, *Acer ginnala*, *Cotoneaster multiflorus*, *Anemone tomentosa*, *Lonicera maackii*, *Lonicera hispida*, *Rubus mesogaenus*, *Pyrus betulaefolia*, *Vitis piasezkii*, *Cerasus polytricha*, *Prunus davidiana*, *Hemistepta lyrata*, *Dioscorea opposita*, and *Crataegus kensuensis.*

The third and forth type (alliances) are characterized based on precipitation and soils (Fig. 4). The third type is the *Viburnum schensianum-Quercus liaotungensis* forest (i.e. the Viburno schensiano-Quercion liaotungensis), which grows on drier soils derived from granite and limestone, and is characterized by species such as *Lonicera ferdinandii*, *Cotoneaster acutifolius*, *Polygonatum sibiricum*, *Viburnum schensianum*, *Pinus tabulaeformis*, *Rosa hugonis*, *Prunus tomentosa*, *Cotoneaster submultiflorus*, and *Cotoneaster zabelii.* Another sub-type is *Viburnum sympodiale-Quercus liaotungensis* forest (i.e. the Viburno sympodiale-Quercion liaotungensis), which occurs in the Loess hills; the character and differential species are *Lespedeza juncea*, *Viburnum sympodiale*, *Rubia lanceolata*, *Carpesium abrotanoides*, *Celtis bungeana*, *Miscanthus sacchariflorus*, *Polygonatum cirrhifolium*, *Syringa komarowi*, *Euonymus verrucosoides*, *Ixeris polycephala*, *Periploca sepium*, *Caragana arborescens*, *Aspidistra elatior*, *Polygonatum verticillatum*, *Koelreuteria paniculata*, *Ailanthus altissima*, *Neottianthe pseudodiphylax*, *Epipactis helloborine*, *Asparagus densiflorus,* etc. Further, these two sub-types are classified, respectively, into three and two kinds (suballiances), based on humidity and human impact. *Acer ginnala-Quercus liaotungensis* forests include three kinds, namely *Litsea pungens-Quercus liaotungensis* forests (the Litso pungens-Quercenion liaotungensis) occurring in ecotones between forest and steppe; *Hippophae rhamnoides-Quercus liaotungensis* forests (the Hippophae rhamnoides-Quercenion liaotungensis) occurring on the edge of steppes; and *Berberis giraldii-Quercus liaotungensis* forests (the Berberio giraldii-Quercenion liaotungensis) occurring in loess region. *Viburnum sympodiale-Quercus liaotungensis* forests include two kinds: *Platycladus orientalis-Quercus liaotungensis* forests (the Platyclado orientalis-Quercenion liaotungensis) in areas of heavy human disturbance; and *Sophora*

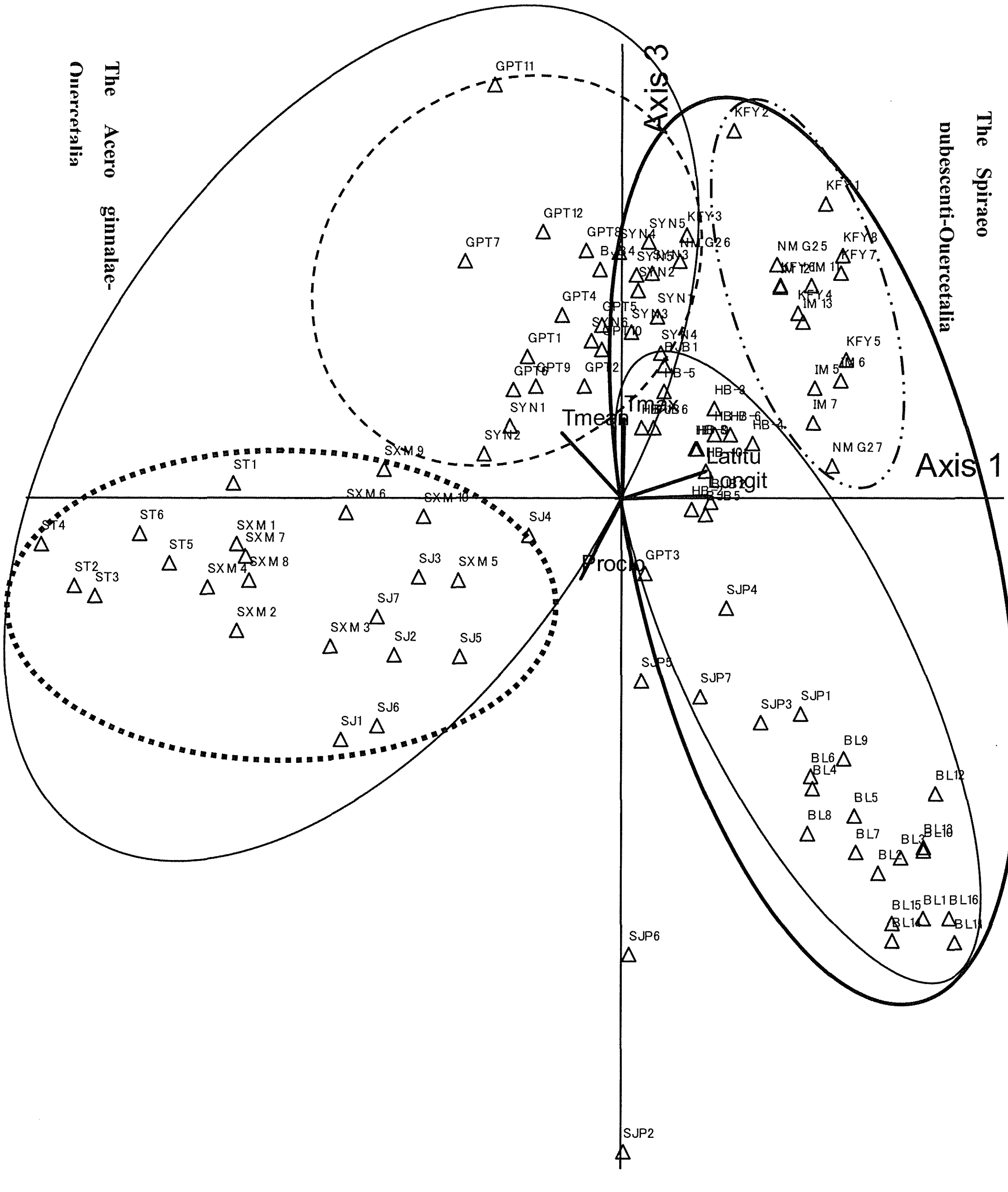


Fig. 3 Detrended Correspondence Analysis (DCA) biplot ordination of study sites and major environmental factors of *Quercus liaotungensis* forest in China.

alopecuroides-Quercus liaotungensis forests (the Sophoro aloecuroides-Quercenion liaotungensis) in the dry loess hills.

The attributes of the structural differentiation, especially dominators of each stratum in the plant community, vary according to with geographic location. The geographical types of *Quercus liaotungensis* forests are classified by structural differentiation, as shown in Figure 4.

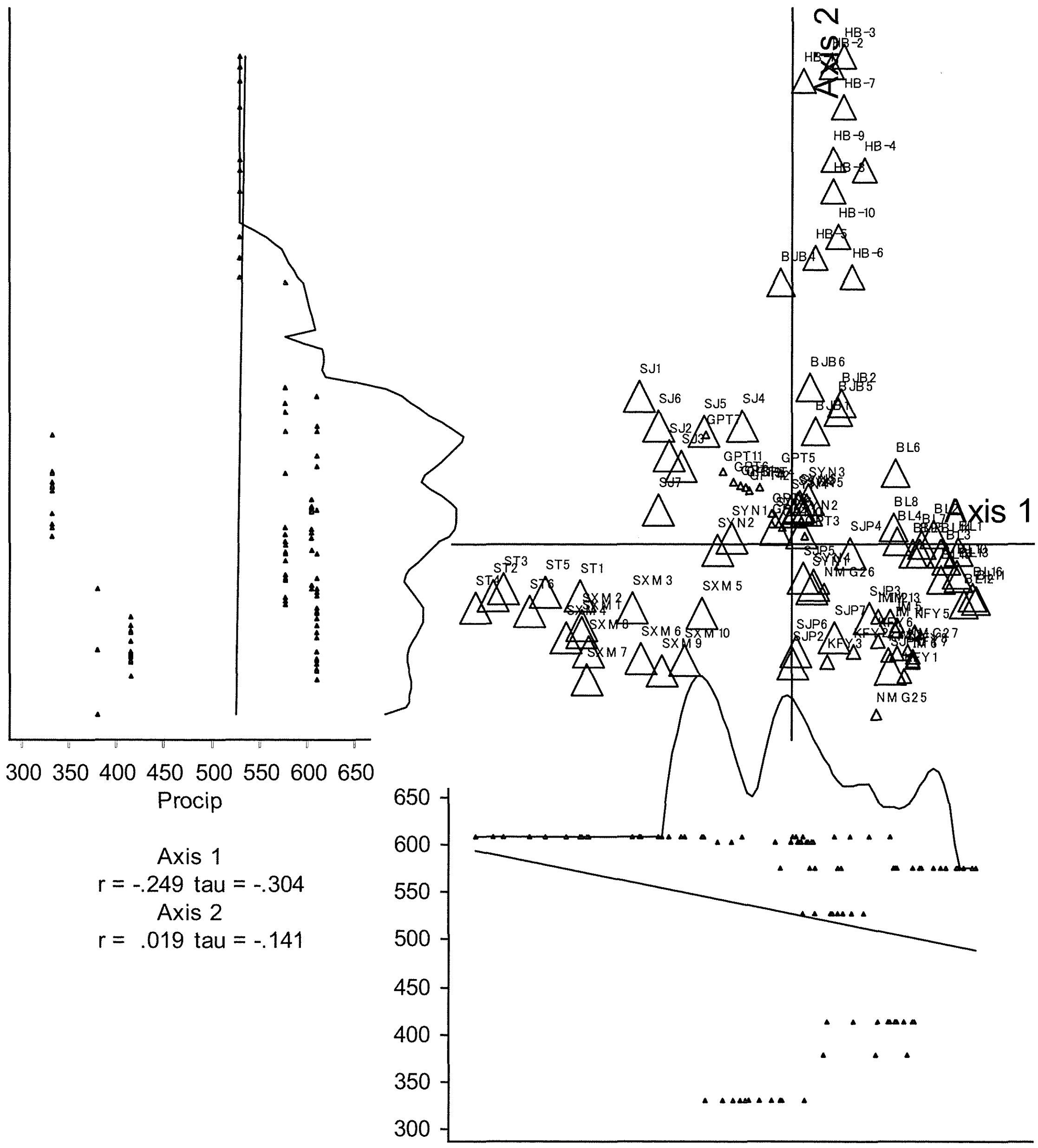


Fig. 4 Detrended Correspondence Analysis biplot ordination of study sites and major environmental factors of *Acer ginnala-Q. liaotungensis* forest in China

Table 1. Summary table of Quercus liaotungensis forests in China

Group number		NM	NM	NM	BJB	BL	HB	SJ	G	ST	SJP	GPT	SXMn	Niwn	Niwn	Niwn	Niwi	angli	iangli	iangling
Number of relevés		6	8	3	8	16	10	7	7	6	10	12	10	11	19	41	19	7	6	7
Mean number of species per relevés		42	44	39	27	48	33	35	50	47	39	40	49	42	38	26	29			
Differential species of the *Paeonio lactiflora-Quercus liaotungensis* community in Inner Mongolia:																				
Paeonia lactiflora	H	IV	IV	3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Artemisia sacrorum	H	III	II	2	·	·	·	·	·	I	·	·	·	III	·	·	·	·	·	·
Silene repens	H	II	IV	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Euphorbia esula	H	II	II	2	·	·	·	·	·	·	·	I	III	·	·	·	·	·	·	·
Geranium sibiricum	H	I	III	1	·	·	·	·	·	·	·	·	II	·	·	·	·	·	·	·
Achnatherum sibiricum	H	V	·	2	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Differential species of subunits:																				
Artemisia igniaria	H	V	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Crataegus pinnatifida	T2,S,H	V	·	·	·	·	·	·	·	·	·	·	·	II	·	·	·	·	·	·
Galium boreale	H	V	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Scutellaria scordifolia	H	IV	·	1	·	·	·	·	·	·	·	I	·	·	·	·	·	·	·	·
Viola verecunda	H	IV	I	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Moehringia laterflora	H	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Artemisia rubripes	H	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Potentilla repens var. *sericoph*	H	III	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Vicia gigantea	H	III	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Asparagus shoberioides	H	III	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Heteropappus altaicus var. *mii*	H	III	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Adenophora stenanthina	H	·	V	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Galium verum	H	·	IV	2	·	II	·	·	·	·	I	·	·	·	·	·	·	·	·	·
Artemisia princeps	H	·	IV	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Carex humilis	H	·	II	3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Hypericum attenuatum	H	·	II	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Valeriana alternifolia	H	·	II	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Thalictrum ichangensis	H	·	V	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Potentilla fragarioides	H	I	IV	·	·	·	+	·	·	·	·	+	I	·	·	·	·	·	·	·
Deyeuxia angustifolia	H	·	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Diarrhena yabeana	H	·	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Saussurea sylvestres	H	·	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Stellera chamaejasme	H	·	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Tilia mongolica	T1,T2,S,H	I	III	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Potentilla discolor	H	·	III	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Lamium album	H	·	III	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Adenophora gmelinii	H	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Hemerocallis minor	H	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Artemisia lactifolia	H	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Artemisia eriopoda	H	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Melilotoides ruthenica	H	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Stemmacantha uniflora	H	·	·	2	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Scorzonera albicaulis	H	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Differential species of the *Artemisia gmelinii-Quercus liaotungensis* community																				
Thalictrum baicalense	H	IV	·	·	V	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Artemisia gmelinii	H	·	·	·	IV	·	·	·	·	·	·	·	+	+	·	·	·	·	·	·
Characteristic and differential species of the Aceri truncatum-Quercetum liaotungensis (Ass. prov.)																				
Clematis brevicaudata	S,H	·	·	·	·	V	·	·	·	·	·	·	II	·	·	·	·	·	·	·
Acer truncatum	T1,T2,S,H	·	·	·	·	V	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Rhamnus utilis	S,H	·	·	·	·	V	·	·	·	I	·	·	I	I	·	·	·	I	·	II
Betula davurica	T1,T2,S	·	III	·	I	IV	·	·	·	·	I	·	·	·	·	·	·	·	·	·
Plectranthus glaucocalyx	H	·	·	·	·	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Syringa villosa	H	·	·	·	·	IV	·	·	·	·	·	·	·	·	·	·	I	·	·	·
Rumex acetosa	H	·	·	1	·	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Carex rigescens	H	·	·	·	·	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Syringa reticulata var. *mandsh*	T2,S,H	·	·	·	·	III	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Dracocephalum moldavica	H	·	·	·	·	III	·	·	·	·	·	·	I	·	·	·	·	·	·	·
Duchesnea indica	H	·	·	·	·	III	·	·	·	·	·	·	·	·	·	I	·	·	·	I
Doellingeria scaber	H	·	·	·	·	III	·	·	·	·	I	·	·	·	·	·	·	·	·	·
Characteristic and differential species of the Syringa pubescens-Quercetum liaotungensis (Ass. prov.)																				
Syringa pubescens	S,H	·	·	·	·	·	IV	·	·	·	·	+	·	I	·	·	·	·	·	·
Indigofera kirilowii	S,H	·	·	·	·	·	IV	·	·	·	·	+	II	·	·	·	·	·	·	·

Crataegus sanguinea	T2,S	I	·	1	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·	·
Arisaema consanguineum	H	·	·	·	·	·	Ⅲ	·	·	·	·	·	+	·	·	·	·	·	·	·
Ajuga nipponensis	H	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·	·
Viola chaerophylloides	H	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·	·
Clematis heracleifolia	S,H	·	·	·	I	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·	·
Character species of the Deutzio parviflora-Quercion liaotungensis in Ji-Liao Mountains (all. prov.)																				
Syringa pekinensis	T2,S,H	·	·	·	Ⅳ	Ⅲ	Ⅲ	·	·	·	·	·	·	Ⅳ	·	·	·	·	·	·
Deutzia parviflora	S,H	·	·	·	Ⅲ	Ⅲ	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·	·
Saussurea nivea	H	·	I	3	V	Ⅳ	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Fraxinus rhynchophylla	T1,T2,S,H	·	·	·	V	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·	·
Spiraea trilobata	S,H	·	·	·	Ⅲ	·	V	·	·	·	·	I	·	·	·	·	·	·	·	·
Synurus deltoides	H	·	I	·	·	Ⅲ	Ⅳ	I	·	·	·	·	·	·	·	·	·	·	·	·
Adenophora divaricata	H	·	·	·	Ⅱ	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Calamagrostis epigeios	H	·	·	·	Ⅱ	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Differential species of the *Euonymus bungeana-Quercus liaotungensis* community																				
Deutzia grandiflora	S	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·	·	·
Euonymus bungeana	S,H	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·	·	·
Crataegus aurantia	T2,S,H	·	·	·	·	·	·	V	·	I	·	·	·	·	·	·	·	·	·	·
Artemisia capillaris	H	·	·	·	·	·	·	V	·	·	·	·	·	Ⅱ	·	·	·	·	·	·
Lonicera microphylla	S,H	·	·	·	·	·	·	Ⅳ	·	·	·	+	I	·	·	·	·	·	·	·
Tilia paucicostata	T1,T2,S,H	·	·	·	·	·	·	Ⅳ	Ⅲ	·	·	·	·	·	·	I	·	·	·	·
Syringa pubescens subsp. *micr*	T2,S,H	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·	·
Differential species of the *Acer grosseri-Quercus liaotungensis* community																				
Thalictrum minus var. *hypoleu*	H	·	I	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·	·
Aster ageratoides var. *heterop*	H	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·	·
Rosa omeiensis	S,H	·	·	·	·	·	·	·	Ⅳ	·	·	·	·	·	·	·	·	·	·	·
Picea wilsonii	S	I	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Stipa przewalskii	H	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Aneurolepidium chinense	H	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Euphorbia micractina	H	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Poa versicolor ssp. *ochotensis*	H	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Nellia sinensis	S	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Smilax glabra	H	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Schisandra sphenanthera	T2,S,H	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Artemisia sylvatica	H	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Ribes graciale	S	·	·	·	·	·	·	I	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Rubus coreanus	S,H	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Indigofera potaninii	S,H	·	·	·	·	·	·	·	Ⅲ	·	·	+	·	·	·	·	·	·	·	I
Acer grosseri	T2,S	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·	·
Euonymus przewalskii	S,H	·	·	·	·	·	·	·	Ⅲ	·	Ⅱ	·	I	·	·	·	·	·	·	·
Quercus spinosa	T1,S,H	·	·	·	·	·	·	·	Ⅱ	·	·	·	·	·	·	·	·	·	·	·
Differential species of the *Quercus aliena-liaotungensis* community																				
Quercus aliena	T1,T2,S,H	·	·	·	·	·	·	·	I	V	·	·	Ⅱ	·	·	·	·	·	·	·
Cotinus coggygia var. *pubesce*	T2,S,H	·	·	·	·	·	I	·	·	V	·	·	·	·	·	·	·	·	·	·
Viburnum betulifolium	S,H	·	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·
Foresythia giraldana form. *pu*	S	·	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·
Adenophora paniculata	H	·	·	·	I	I	·	·	I	V	·	I	Ⅱ	Ⅱ	·	·	·	·	·	·
Acer davidii	T2,S,H	·	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·
Lonicera tragophylla	S,H	·	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	Ⅱ	I
Thalictrum macrorhynchum	H	·	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·
Adenophora hunanensis	H	·	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·	·	·
Ligularia veitschiana	H	·	·	·	·	·	·	·	·	Ⅳ	·	·	·	·	·	·	·	·	·	·
Wikstroemia micrantha	S,H	·	·	·	·	·	·	·	·	Ⅳ	·	·	·	·	·	·	·	·	·	·
Rhus succedanea	T1,T2,S,H	·	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·
Ophiopogon japonicus	H	·	·	·	·	·	·	·	·	Ⅲ	·	·	·	·	·	·	·	·	·	·
Syneilensis aconitifolia	H	·	·	·	·	·	·	·	·	Ⅲ	·	I	·	·	·	·	·	·	·	·
Indigofera amblyantha	S,H	·	·	·	·	·	·	I	·	Ⅲ	·	·	+	·	·	·	·	·	·	·
Characteristic species of the Litso pungens-Querceni on liaotungensis (suball. prov.)																				
Asparagus filicinus	H	·	·	·	·	·	·	·	V	Ⅲ	·	Ⅱ	I	·	·	·	·	·	·	·
Epimedium brevicorum	H	·	·	·	·	·	·	·	Ⅳ	Ⅱ	·	Ⅲ	·	·	·	·	·	I	·	·
Litsea pungens	T2,S,H	·	·	·	·	·	·	·	Ⅲ	V	·	·	·	·	·	·	·	·	·	·
Lindera obutusiloba	T2,S	·	·	·	·	·	·	·	Ⅲ	Ⅲ	·	·	·	·	·	·	·	·	·	·
Berberis dielsiana	S,H	·	·	·	·	·	·	·	Ⅲ	Ⅱ	·	·	·	·	·	·	·	·	·	·
Euonymus porphyreus	S	·	·	·	·	·	·	·	Ⅲ	Ⅱ	·	·	+	·	·	·	·	·	·	·
Pinus armandii	T1,T2,S,H	·	·	·	·	·	·	·	Ⅲ	I	·	·	·	·	·	·	·	·	·	·

Sorbaria kirilowii	S,H	·	·	·	·	·	·	·	III	I	·	I	·	+	·	·	·	·	·	·
Chimaphylla japonica	H	·	·	·	·	·	·	·	II	III	·	·	·	·	·	·	·	·	·	·
Berchemia sinica	S,H	·	·	·	·	·	·	·	II	II	·	·	·	·	·	·	·	·	·	·
Differential species of the Ribes burejense-Quercetum liaotungensis (ass. prov.)																				
Picea meyeri	T1,T2,S,H	·	·	·	·	·	·	·	·	·	IV	·	+	·	·	·	·	·	·	·
Ribes burejense	S,H	·	·	·	·	·	·	·	·	·	IV	·	·	·	·	·	·	·	·	·
Cardamine leucantha	H	·	·	·	·	+	·	·	·	·	IV	·	·	·	·	·	·	·	·	·
Larix principis-rupprechtii	T1,T2,H	·	·	I	·	·	·	·	·	·	III	+	·	·	·	·	·	·	·	·
Clematis macropetala	S,H	II	·	·	·	·	·	·	·	I	III	·	·	·	·	·	·	·	·	·
Daphne giraldii	S,H	·	·	·	·	·	·	·	·	·	III	+	·	·	·	·	·	·	·	·
Characteristic and differential species of the Stephanandro incisa-Quercetum liaotungensis (ass. prov.)																				
Thalictrum foetidum	H	·	·	·	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·	·
Aconitum sungpanense	H	·	·	·	·	·	·	·	III	·	·	IV	+	·	·	·	·	·	·	·
Rubus pungens var. *indefensus*	S,H	·	·	·	·	·	·	·	·	·	·	III	·	·	·	·	·	·	·	·
Stephanandra incisa	S,H	·	·	·	·	·	·	·	·	·	·	III	·	·	·	·	·	·	·	·
Characteristic and differential species of the Carici onoei-Quercetum liaotungensis (ass. prov.)																				
Carex onoei	H	·	·	·	I	·	·	·	·	·	·	·	V	·	·	·	·	·	·	·
Ajuga ciliata	H	·	·	·	·	·	·	·	·	·	·	·	IV	·	·	·	·	·	·	·
Adenophora elata	H	·	·	·	·	·	·	·	·	·	·	·	III	·	·	·	·	·	·	·
Character species of the Hippophae rhamnoides-Quercenion liaotungensis (suballiance)																				
Corylus mandshurica	T2,S,H	·	·	·	·	IV	·	·	·	·	IV	III	II	·	·	·	·	·	·	·
Fragaria orientalis	H	·	I	I	·	·	·	·	II	·	IV	II	I	·	·	·	·	·	·	·
Arundinella hirta	H	·	·	·	·	·	·	·	·	·	IV	I	+	·	·	·	·	·	·	·
Adenophora polyantha	H	·	·	·	·	II	·	·	·	I	III	III	II	·	·	·	·	·	·	·
Hemerocallis flava	H	·	·	·	·	+	·	·	I	·	II	III	I	·	·	·	·	·	·	·
Hippophae rhamnoides	T2,S,H	·	·	·	·	·	·	·	·	·	II	I	II	·	·	·	·	·	·	·
Daucus carota	H	·	·	·	·	+	·	·	·	·	II	+	III	III	·	·	·	·	·	·
Saussurea pectinata	H	·	·	·	·	·	·	·	·	·	I	III	IV	·	·	·	·	·	·	·
Galium aparine	H	II	·	·	·	·	·	·	·	·	I	I	II	·	·	·	·	·	·	·
Indigofera bungeana	S,H	·	·	·	·	I	·	·	·	·	II	·	II	·	·	·	·	·	·	·
Differential species of the ***Berberis giraldii-Querccus liaotungensis*** community																				
Berberis giraldii	S,H	·	·	·	·	·	·	·	·	·	·	·	·	III	I	·	·	·	·	·
Euonymus phellomanus	T,S,H	·	·	·	·	·	+	·	I	·	·	·	·	III	·	·	·	·	·	·
Rubus parvifolius	S,H	·	·	·	·	·	+	·	I	I	·	·	·	III	·	·	·	·	·	·
Acanthopanax stuchuensis	S,H	·	·	·	·	·	·	·	I	·	·	·	·	II	·	·	·	·	·	·
Character species of the Viburno schensiano-Quercion liaotungensis (all. prov.)																				
Viburnum schensianum	S,H	·	·	·	·	·	·	IV	II	V	I	III	III	III	·	·	·	·	·	·
Pinus tabulaeformis	T,S,H,	·	·	·	II	·	·	I	I	II	II	II	+	I	·	·	·	I	·	·
Rosa hugonis	T2,S,H	·	·	·	·	·	·	III	III	I	+	V	I	·	·	·	·	·	·	·
Prunus tomentosa	T2,S,H	·	·	·	·	·	·	III	III	V	·	II	+	III	·	·	·	·	·	·
Cotoneaster submultiflorus	S	·	·	·	·	·	·	I	·	·	IV	III	III	I	·	·	·	·	·	·
Cotoneaster zabelii	S	·	·	·	·	·	·	III	II	I	·	+	·	I	·	·	·	·	·	·
Characteristic and differential species of the Platyclado orientalis-Quercetum liaotungensis (ass. prov.)																				
Lonicera stephanocarpa	T,S,H	·	·	·	·	·	·	·	·	·	·	·	·	·	III	I	II	·	·	·
Acer stenolobum	T,S,H	·	·	·	·	·	·	·	·	·	·	·	·	II	II	III	IV	·	·	·
Sonchus oleraceus	H	·	·	·	·	·	·	·	·	·	·	·	·	·	III	I	I	·	·	·
Syringa vulgaris	T,S,H	·	·	·	·	·	·	·	·	·	·	·	·	·	II	II	I	·	·	·
Bothriospermum chinense	H	·	·	·	·	·	·	·	·	·	·	·	·	·	II	I	I	·	·	·
Platycladus orientalis	T,S,H	·	·	·	·	·	·	·	·	+	·	·	·	+	I	I	II	·	·	·
Epilobium cephalostigma	H	·	·	·	·	·	·	·	·	·	·	·	·	·	I	I	I	·	·	·
Bidens bipinnata	H	·	·	·	·	·	·	·	·	·	·	·	·	·	I	I	I	·	·	·
Aristolochia contorta	H	·	·	·	·	·	·	·	·	·	·	·	·	·	III	I	·	·	·	·
Characteristic and differential species of the Sophoro aloecuroides-Quercetum liaotungensis (ass. prov.)																				
Toxicodendron vernicifluum	T,S,H	·	·	·	·	·	I	·	III	II	·	·	·	·	·	·	·	III	II	III
Sophora alopecuroides	S,H	·	·	·	·	·	·	·	·	·	·	·	III	·	·	·	·	II	III	III
Cornus macrocarpa	S,H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	III	II
Clematis pogonandria	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	III	II	I
Lotus corniculatus	T,S,H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	I	IV
Vicia villosa	H	·	·	·	·	·	·	·	·	·	·	·	·	I	·	·	·	II	I	II
Rhus potaninii	T2,S,H	·	·	·	·	·	·	·	III	I	·	+	+	·	·	·	·	I	V	III
Glechoma longituba	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	III	V
Viola yedoensis	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	III	·	I
Clematis aethusifolia	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	IV	I
Vitex negundo	S,H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	III	I
Lespedeza tomentosa	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	III

Character species of the Viburno sympodiale-Quercion liaotungensis (all. prov.)

Lespedeza juncea	H	·	·	·	·	·	·	·	·	·	·	·	·	·	IV	III	III	II	V	V
Viburnum sympodiale	S,H	·	·	·	·	·	·	·	·	·	·	·	·	·	III	V	IV	IV	V	V
Rubia lanceolata	H	·	·	·	·	·	·	·	·	·	·	I	+	II	II	II	III	III	IV	III
Carpesium abrotanoides	H	·	·	·	·	·	·	·	·	·	·	·	·	·	II	I	I	V	V	III
Celtis bungeana	T,S,H	·	·	·	·	·	·	·	·	III	·	·	·	·	II	I	·	I	I	I
Miscanthus sacchariflorus	H	·	·	·	·	·	·	·	·	+	·	·	·	·	·	I	I	II	I	V
Polygonatum cirrhifolium	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	I	I	V	I
Syringa komarowi	T,S,H	·	·	·	·	·	·	·	·	·	·	·	·	III	III	V	IV	II	·	·
Euonymus verrucosoides	T,S,H	·	·	·	I	·	·	·	II	·	·	·	·	·	III	II	II	·	I	·
Ixeris polycephala	H	·	·	·	·	·	·	·	·	·	·	·	·	·	III	II	I	III	·	·
Periploca sepium	H	·	·	·	·	·	·	·	·	·	·	·	+	·	III	II	II	·	II	·
Caragana arborescens	T,S,H	·	·	·	·	·	·	·	·	·	·	·	·	·	II	V	IV	III	·	·
Aspidistra elatior	H	·	·	·	·	·	·	·	·	·	·	·	·	·	II	III	I	I	·	·
Polygonatum verticillatum	H	I	·	·	·	·	·	·	·	·	·	·	·	·	II	III	II	I	·	·
Koelreuteria paniculata	T,S,H	·	·	·	·	·	·	I	I	·	·	·	·	·	II	II	I	·	II	·
Ailanthus altissima	T,H	·	·	·	·	·	·	·	·	·	·	·	·	·	II	I	I	·	·	I
Neottianthe pseudodiphylax	H	·	·	·	·	·	·	·	·	·	·	·	·	·	II	I	I	II	·	·
Epipactis helloborine	H	·	·	·	·	·	·	·	I	I	·	·	·	·	II	·	I	·	IV	V
Asparagus densiflorus	H	·	·	·	·	·	·	·	·	·	·	·	·	·	I	I	I	I	·	·

Characteristic and differential species of the Acero ginnalae-Quercetalia liaotungensis in Loess Plateau(order)

Elaeagnus umbellata	S,H	·	·	·	·	·	·	·	I	III	I	+	II	III	I	I	I	II	I	IV
Cotoneaster multiflorus	S,H	·	·	·	I	·	·	·	IV	IV	I	II	I	II	IV	V	V	III	·	I
Anemone tomentosa	H	·	·	·	·	·	·	·	I	I	·	I	II	III	II	I	I	IV	III	V
Acer ginnala	T1,T2,S,H	II	·	·	·	·	·	·	·	III	IV	·	IV	IV	III	IV	III	IV	V	V
Lonicera maackii	T,S,H	·	·	·	·	I	·	·	·	+	III	·	+	IV	III	I	I	II	II	II
Lonicera hispida	S,H	·	·	·	·	·	·	I	·	II	I	·	+	II	I	IV	II	III	V	III
Rubus mesogaenus	H	·	·	·	·	·	·	·	I	·	·	+	+	III	IV	II	III	III	III	II
Pyrus betulaefolia	T2,S,H	·	·	·	·	·	·	·	·	I	·	III	III	V	·	I	I	III	I	II
Vitis piasezkii	H	·	·	·	·	·	·	·	·	·	·	III	+	III	V	IV	V	III	V	II
Cerasus polytricha	T,S,H	·	·	·	·	·	·	·	·	·	·	I	IV	III	III	III	III	III	II	II
Prunus davidiana	T,S,H	·	·	·	·	·	I	I	·	I	·	I	IV	II	·	I	I	·	I	I
Hemistepta lyrata	H	·	·	·	·	·	II	·	·	·	·	II	+	III	I	I	·	III	II	III
Dioscorea opposita	H	·	·	·	·	·	·	·	·	·	·	·	III	III	IV	V	IV	V	III	II
Crataegus kensuensis	S,H	·	·	·	·	I	·	·	V	I	IV	V	·	IV	·	·	·	·	III	III

Character species of the Quercetea liaotungensis in China(Class)

Quercus liaotungensis	T1,T2,S,H	V	V	3	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Spiraea pubescens / hirsuta	S,H	V	V	3	V	V	V	V	·	V	V	V	V	IV	IV	V	III	IV	II	III
Ostryopsis davidiana	S,H	V	V	3	·	·	·	II	II	I	·	I	V	IV	I	II	II	III	II	III
Rosa xanthina	S,H	I	IV	·	·	·	·	III	·	I	·	I	V	II	I	III	IV	III	IV	IV
Prunus sibiricus	T2,S,H	III	III	2	IV	·	·	I	·	I	II	+	+	II	I	II	II	·	·	·
Ulmus macrocarpa	T1,T2,S,H	III	II	1	II	+	·	II	I	·	·	·	·	II	I	I	I	·	·	·
Lonicera ferdinandii	T2,S,H	·	·	·	·	·	IV	V	III	III	I	IV	IV	III	·	·	·	·	·	·
Cotoneaster acutifolius	T2,S,H	V	I	·	·	I	·	V	II	I	III	II	II	III	·	·	·	·	·	·
Polygonatum sibiricum	H	I	·	·	II	·	I	IV	III	III	III	IV	II	II	·	·	·	·	·	·
Smilax stans	S,H	·	·	·	·	·	IV	I	IV	V	·	III	+	·	·	·	·	III	·	·
Abelia biflora	T2,S,H	·	·	·	·	IV	III	III	·	III	·	·	·	·	·	·	·	·	·	·
Carpinus turczaninowii var. *st*	T1,T2,S,H	·	·	·	·	·	V	V	I	II	·	·	·	·	·	·	·	·	·	·
Philadelphus pekinensis var. *d*	S,H	·	·	·	·	·	II	III	·	·	·	·	·	·	·	·	·	·	·	·
Atractylodes lancea	H	IV	I	·	IV	I	III	·	I	V	·	·	IV	·	·	·	·	·	I	I

Other species

Carex lanceolata	H	V	V	2	V	III	V	IV	IV	V	V	V	·	V	V	V	V	V	V	V
Polygonatum odoratum	H	I	V	2	V	V	III	III	III	V	V	V	III	V	I	IV	I	V	V	III
Rubia cordifolia	S,H	V	I	·	II	III	III	II	IV	IV	V	III	III	I	II	I	·	I	III	I
Agrimonia pilosa	H	IV	·	1	II	V	·	II	·	I	II	II	II	III	I	I	·	II	II	III
Lespedeza bicolor	T2,S,H	II	V	3	V	IV	IV	·	III	I	IV	V	III	I	·	I	·	I	·	·
Euonymus alatus	S,H	·	·	·	·	+	II	·	III	IV	·	II	I	IV	II	I	I	III	V	III
Leibnitzia anandria	H	II	II	·	·	III	·	·	·	I	II	III	V	II	I	·	I	IV	II	III
Celastrus orbiculatus	T1,T2,S,H	·	·	·	·	·	I	I	·	IV	·	·	I	III	IV	II	II	III	IV	III
Viola collina	H	III	II	·	·	I	III	·	III	·	I	II	IV	II	·	·	·	III	III	III
Aster ageratoides	H	IV	IV	·	V	IV	III	IV	·	V	III	III	V	V	·	·	·	·	·	·
Dioscorea nipponica	T2,S,H	IV	I	·	IV	V	IV	IV	V	V	·	III	·	I	·	·	·	·	·	·
Sedum aizoon	H	II	V	3	I	III	I	·	III	·	II	·	II	·	·	·	·	·	I	·
Vicia unijuga	H	II	V	3	·	·	II	I	II	II	I	·	·	·	·	·	·	·	·	·
Spodiopogon sibiricus	H	·	I	2	II	I	III	·	·	II	·	II	V	I	·	·	·	·	·	·

Lonicera chrysantha	S,H	V	II	·	·	I	IV	V	III	·	II	+	·	I	·	·	·	·	·	·
Corylus heterophylla	T2,S	·	·	·	I	·	·	·	V	·	·	IV	I	+	I	I	I	·	·	·
Veratrum nigrium	H	·	III	3	II	IV	·	I	·	I	I	III	·	·	·	·	·	·	·	·
Berberis amurensis	S,H	II	II	·	·	I	·	I	·	·	II	III	II	·	·	·	·	·	·	·
Acer mono	T1,T2,S,H	·	IV	·	I	·	IV	V	III	·	·	·	·	·	·	·	·	·	·	·
Convallaria majalis	H	·	II	·	I	III	·	I	·	·	·	II	·	·	·	·	·	·	·	·
etc.																				

2) Warm temperate deciduous forest: Phytosociological study of deciduous broad-leaved forests in the temperate zone of China. I. Characteristics of different plant communities

Tang Qian & Kazue Fujiwara (*Institute of Environmental Science and Technology, Yokohama National University, Tokiwadai 79-7, Hodogaya-Ku, Yokohama City, Kanagawa Prefecture, 240-8501, Japan)*

You Hai-Mei (*Institute of City and Environment, Xuzhou Normal University, Shanghai Road 29, Tong Shan County, Xuzhou City, Jiangsu Province, 221116, China*)

Abstract: Based on the Braun-Blanquet methodology, this study investigated deciduous broad-leaved forests in the so-called warm-temperate zone of China. Seventy relevés were gathered and classified into six types of plant community. We describe each type of community, including characteristics of its distribution area, community structure, and species composition. According to this basic analysis, we can find that *Quercus aliena* forest, occurring in Henan Province, is being well protected and shows better development than *Quercus liaotungensis* forest in north and northwest of China.

Key words: deciduous broad-leaved forest, warm-temperate zone of China, Braun-Blanquet methodology, characteristics of plant community, *Quercus liaotungensis* forest, *Quercus aliena* forest

Introduction

Deciduous broad-leaved forest is the typical vegetation type in the Chinese bioclimatic zone called warm-temperate (typical temperate elsewhere). Such forests range from 32°30′ to 42°30′ N latitude and from 103°30′ to 124°10′ E longitude (Wu 1980). In this area, the main deciduous broad-leaved tree families and genera are as follow: Fagaceae, including *Quercus*, *Castanea*, and *Fagus*; Betulaceae, which includes *Betula*, *Carpinus*, and *Alnus*; Ulmaceae, involving *Ulmus*, *Celtis*, and *Pteroceltis*; *Acer*; Salicaceae, including *Populus*; Hamamelidaceae, with *Liquidambar*, and so on. Compared with other species, *Quercus* spp. are always dominant in the tree layer and often form *Quercus* mixed forests in this temperate zone of China. Otherwise, such forest types as *Populus davidiana* or *Betula platyphylla* are also commonly seen in this area.

The first systematic, comprehensive introduction to the vegetation in temperate China was published in the *Vegetation of China* (Wu 1980). Since then there have been few publications of vegetation-ecological research about this region (Chen et al. 1997; Gao et al. 2002). Recently, some phytosociological studies based on the Braun-Blanquet methodology were performed on the vegetation of northeastern China (Yu et al. 2001; Wang et al. 2006) and in the lower stretches of the Yangtze River (Suzuki et al. 2002, 2003). Even so, phytosociological studies for temperate China are rarely seen. Phytosociological study using the Braun-Blanquet method has been performed in Western countries for a long time. The Braun-Blanquet methodology is very useful to ecologists in that it facilitates construction of data-bases (of vegetation relevés), which make it possible for researchers to compare relevé data from other places. The Chinese flora plays an important role in geobotany. It is thus necessary and meaningful to do comparative analyses with the vegetation of other countries. Using the Braun-Blanquet methodology to study vegetation will be very beneficial for future ecological research of China.

This study attempts to analyze the deciduous broad-leaved forests in temperate China using the Braun-Blanquet methodology. For this paper, we analyze the situation and characteristics of current plant communities in this region. In the future, we hope to analyze the relationships between plant communities and environmental factors, and to compare with Japanese deciduous broad-leaved forests.

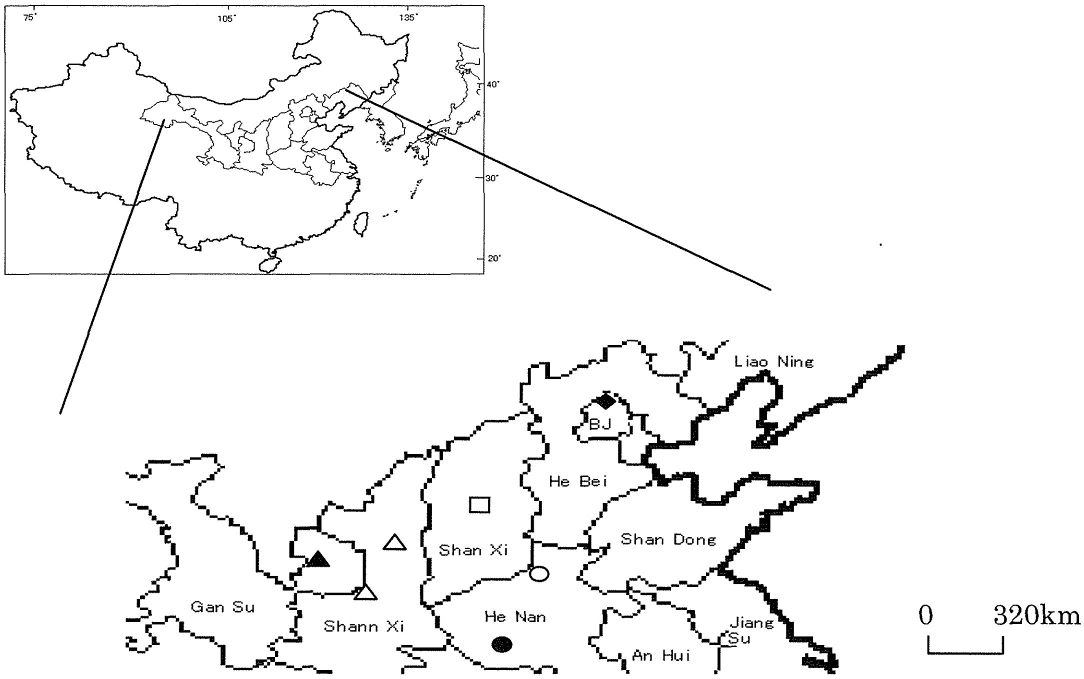


Fig. 1. Location of the Study Area in the "warm-temperate" Zone of China, with main community types.

◆ *Acer truncatum-Quercus liaotungensis* community

○ *Quercus variabilis-Quercus aliena* community

● *Schisandra pubescens-Quercus aliena* community

□ *Picea meyeri-Quercus liaotungensis* community

△ *Pyrus betulaefolia-Quercus liaotungensis* community

▲ *Rosa hugonis-Quercus liaotungensis* community

Methods

Study area

The study area is in the so-called warm-temperate zone of China, where seven study sites were surveyed (see Fig. 1). In this area the mean annual temperature is 8-14°C, the average temperature of the coldest month (January) is -3 to -22°C, and the average temperature of the warmest month (July) is 24-28°C. The average elevation is more than 1500m. Mean annual precipitation is 500-1000 mm. Soil types of this region are brown forest soil and drab soil. The typical forest type in this area is deciduous broad-leaved forest.

Vegetation investigation and analysis

The vegetation was investigated from May to August, 2007. Seventy relevés were recorded by Braun-Blanquet methodology, in Beijing City and in four other provinces of this region (Henan, Gansu, Shanxi, and Shaanxi). In addition to recording the species composition, cover, and occurrence frequency in the vegetation, we also recorded environmental variables in every relevé, including elevation, slope aspect, soil moisture, and slope inclination. We also classified the different types of plant community, based on Braun-Blanquet methodology, describing the characteristics of each community.

Results

Classification

According to the data from the 70 relevés and based on Braun-Blanquet procedures, the deciduous broad-leaved forests in the Chinese zone called warm-temperate can be classified into six main community types: *Schisandra pubescens-Quercus aliena, Quercus variabilis-Quercus aliena*, *Pyrus betulaefolia-Quercus liaotungensis*, *Rosa hugonis-Quercus liaotungensis*, *Picea meyeri-Quercus liaotungensis*, and *Acer truncatum-Quercus liaotungensis*. Some of these communities also have sub-units.

Characteristics of the different plant communities

1. *Schisandra pubescens-Quercus aliena* community (Table 1)

This kind of community occurs mainly in Bao Tian Man Nature Preservation Zone, which is in Nan Yang City in southwestern Henan Province. The character and different species of this community are: *Schisandra pubescens, Rhus verniciflua, Acer grosseri, Cornus kousa* var. *chinensis, Euonymus phellomanes*, *Lindera obtusiloba*, *Rubus palmatus*, *Styrax hemsleyana*, *Abelia biflora* and others.

The *Schisandra pubescens-Quercus aliena* community is located at higher elevation (1270-1690m). It has relatively many species, with mean number of species sometimes reaching 50. The community consists of into four layers. The height of tree layer is 13-19m, and its cover ranges from 65% to 85%. *Acer grosseri, Cornus kousa* var. *chinensis*, and *Quercus glandulifera* var. *brevipetiolata* are the dominant species in the tree layer. The shrub layer has 15%-45% cover, with an average height of 2.4m. The main species in this layer include *Acer grosseri, Cornus kousa* var. *chinensis, Lindera obtusiloba, Viburnum betulifolium*, and *Abelia biflor*. The mean cover of the herb layer is 22%, and its height ranges from 0.4 to 0.8m. Species such as *Phlomis umbrosa*, *Carex subpediformis*, *Deyeuxia arundinacea*, and *Aster ageratoides* are dominant.

This plant community can be divided into two sub-communities:

Carex siderosticta: character and differential species are *Carex siderosticta*, *Malus prunifolia*, *Pyrola rotundifolia*, *Lilium pumilum, Lespedeza buergeri, Sorbus folgneri, Acer griseum, Prunus dielsiana* and others.

Styrax japonicus: *Styrax japonicus* and *Rubus trianthus* are character and differential species in this sub-unit.

2. *Quercus variabilis-Quercus aliena* community (Table 1)

The *Quercus variabilis-Quercus aliena* community is located on Yun Tai Mountain of Jiao Zuo City, in Henan Province. This community can be distinguished from other plant communities by the occurrence of *Quercus variabilis*, *Cotinus coggygria* var. *pubescens*, *Clematis florida*, *Rhamnus davurica*, *Smilax sieboldii*, *Vitis amurensis*, and *Salvia miltiorrhiza*, which are character and differential species.

This plant community occurs at lower elevations of 451 to 1150 m. The average number of species of this community is 47. It can be stratified into 3~4 layers, with the tree layer ranging from 7 to 17m and having an average cover of 78%. *Quercus variabilis* and *Quercus aliena* are the main species in the tree layer and almost constitute it completely. In some relevés, *Carpinus turczaninowii* and *Cotinus coggygria* var. *pubescens* were also found in the top tree layer but in quantities much less than *Quercus variabilis* and *Quercus aliena*. The shrub layer can reach a mean height of 3m, with average cover of 49%. *Cotinus coggygria* var. *pubescens, Viburnum mongolicum*, *Carpinus turczaninowii*, and *Forsythia suspensa* are dominant species in the shrub layer. The average height of the herb layer is 0.47m and mean cover is low at 17%. In this layer the dominant species are *Rubia cordifolia*, *Schisandra sphenanthera*, *Smilax sieboldii*, *Deyeuxia arundinacea* and others.

The *Quercus variabilis-Quercus aliena* community has two sub-units:

Viburnum mongolicum, which can be distinguished by *Rhamnus rugulosa*, *Rhododendron molle, Allium anisopodium*, *Atractylodes macrocephala*, *Crataegus cuneata*, *Syringa microphylla, Sporobolus indicus* and so on.

Juglans regia, which can be differentiated by *Rabdosia inflexa*, *Artemisia shangnanensis*, *Aconitum henryi, Diospyros lotus, Parthenocissus himalayana*, *Akebia trifoliata, Amorpha fruticosa, Juglans regia, Celtis biondii* and so on.

3. *Pyrus betulaefolia -Quercus liaotungensis* community (Table 1)

The *Pyrus betulaefolia -Quercus liaotungensis* community can be found in Ma Lan village and Nan Ni Wan village in Shaanxi Province. Its character and differential species include *Pyrus betulaefolia*, *Ostryopsis davidiana*, *Carpesium cernuum, Cerasus polytricha*, and *Prunus davidiana.*

This community appears at elevations between 1210 and 1420m. Because some of the study sites were near the village and at higher elevation, the *Pyrus betulaefolia-Quercus liaotungensis* community that we sampled was shorter and had a simpler structure than other plant communities. Even so, the mean number of species in this community can reach 59, and it always has three layers. The average height of tree layer is 6.4m, with mean cover about 52%. *Quercus liaotungensis*, *Acer ginnala*, and *Prunus davidiana* are the dominant species in this layer. Shrub-layer height ranges from 1.5 to 3m, and cover 15% to 80%. The dominant species are *Acer ginnala*, *Rosa xanthina*, *Viburnum schensianum*, *Ostryopsis davidiana* and so on. Herb-layer height ranges from 0.3 to 0.8m and average cover reaches about 27%, which is much more than in the other kinds of plant communities seen. Within the herb layer, *Carpesium cernuum*, *Saussurea pectinata*, *Viola collina*, *Polygonatum sibiricum*, *Ostryopsis davidiana*, *Quercus liaotungensis*, *Carex lanceolata*, and *Aster ageratoides* are some of the dominant species.

This community has two sub-units:

Ajuga ciliata, which can be differentiated by *Ajuga ciliate*, *Euphorbia esula*, and *Adenophora elata.*

Rubus parvifolius, in which *Rubus parvifolius*, *Caragana microphylla*, *Berberis brachypoda* , *Acanthopanax setchuensis* , *Acer stenolobum* , *Taraxacum mongolicum* and *Ulmus macrocarpa* are the character and different species.

4. *Rosa hugonis -Quercus liaotungensis* community (Table 1)

The *Rosa hugonis-Quercus liaotungensis* community is located on Pang Tong mountain of Gansu Province, in dry northwestern China. Its character and different species are *Rosa hugonis, Thalictrum foetidum, Aconitum sungpanense, Corylus heterophylla* and *Epimedium brevicornu.*

This kind of plant community occurs at much higher elevation (1840-2160m) and has a simper community structure and lower tree layer. The mean number of species in this community is 51; its tree layer only reaches about 10m and its mean cover is 63%. In the tree layer the dominant species are *Quercus liaotungensis, Crataegus kensuensis, Rhamnus parvifolia, Corylus mandshurica* and others. Shrub-layer cover can reach 36%, with a height of about 2m. *Rosa hugonis, Thalictrum foetidum, Aconitum sungpanense* and *Corylus heterophylla* are dominant species in this layer. The herb layer also has somewhat higher cover at 27%, and its mean height is 0.62m. In this layer, *Carex lanceolata, Deyeuxia arundinacea,* *Bupleurum chinensis, Smilax stans* and so on are the dominant species.

5. *Picea meyeri-Quercus liaotungensis* community(Table 1)

This kind of woody community is found in Pang Quan Gou Preservation Zone in Jiao Cheng City of Shanxi Province. The character and differential species are *Picea meyeri, Ribes burejense, Achnatherum sibiricum, Cardamine leucantha, Clematis macropetala* and *Chenopodium glaucum.*

The *Picea meyeri-Quercus liaotungensis* community can be found in the mountains at elevations of 1650 to 2180m. Average community height is 10.5m, but cover is relatively high at 76%. The dominant species in the tree layer are *Quercus liaotungensis, Betula platyphylla, Syringa pekinensis* and *Picea meyeri.* Shrub-layer mean height is 2.5m and average cover is 20%. Species such as *Rosa acicularis, Syringa pekinensis, Ribes burejense* and *Lespedeza bicolor* are dominant in this layer. The herb layer can reach 0.5m and has a mean cover of 21%. For this layer, *Aconitum coreanum, Thalictrum thunbergii, Angelica sinensis, Saussurea nivea, Achnatherum sibiricum* and so on are dominant species. The average number of species in this community is 49.

6. *Acer truncatum-Quercus liaotungensis* community(Table 1)

The *Acer truncatum-Quercus liaotungensis* community occurs on Ling Mountain of Beijing. The character and different species of this community are *Acer truncatum, Rhamnus utilis, Clematis brevicaudata, Betula davurica, Syringa villosa, Deutzia parviflora, Adenophora divaricata, Duchesnea indica, Dracocephalum moldavica* and so on.

This kind of plant community is found in a relatively narrow elevation range of 1560 to 1750m. The height of this forest is about 9-14m, and its average cover is 73%. Dominant tree-layer species are *Quercus liaotungensis, Betula davurica, Acer truncatum, Abelia biflora, Syringa villosa* and so on. Mean shrub-layer height is 2.2m, and cover of this layer is 15-50%. *Rhamnus utilis*, *Abelia biflora*, *Syringa villosa*, *Spiraea pubescens* and others are dominant species in the shrub layer. The herb layer ranges from 0.4 to 0.8m high, with cover of 10% to 50%. The dominant species in this layer are *Aconitum coreanum*, *Thalictrum thunbergii*, *Angelica sinensis*, *Saussurea nivea* and so on. The average number of species in this plant community is about 56.

Conclusions and discussion

According to the present investigation, data and classification results, there are six main types deciduous broad-leaved forest community in the so-called warm-temperate zone of China. *Quercus liaotungensis* forest occurs in much drier habitats at higher elevation, but *Quercus aliena* forest can always be found much further south and at lower elevation.

We also found that the forests in northwestern China have not been protected well at all. For example, the *Quercus liaotungensis* forests on Pang Tong mountain in Gansu and at Nan Ni Wan in Shaanxi are short and have quite simple structure. Other plant communities, especially the *Quercus variabilis-Quercus aliena* community, which occurs in the nature-preservation zone of Henan, shows characteristics of a natural forest and has been protected for more than 20 years.

References

Chen L.Z., Chen Q.L. and Liu W.H. 1997. *Forest Diversity and Its Geographical Distribution in China*. Institute of Science Press, Beijing.

Sang W.G. 2004. Modelling changes of a deciduous broad-leaved forest in warm-temperate zone of China. *Acta Ecological Sinica*, 6:1194-1198.

Suzuki, S.I., Y. Nakamura, K. Kawano, Wang X.H., and Da L.J. 2003. A phytosociological study on the deciduous oak forests in eastern China. *Eco-Habitat*, 10(1):85-103.

Suzuki, S.I., and A. Miyawaki 2006. Comparison of *Quercus* forests in western Japan and eastern China. *Polish Botanical Studies*, 22:487-501.

Wu Zhenyi 1980. *Zhongguo Zhibei* [Vegetation of China]. Science Press, Beijing.

Wang L., K. Fujiwara, and You H.-M. 2006. A vegetation-ecological study of deciduous broad-leaved forests in Heilongjiang Province, China: species composition, structure, distribution and phytosociological scheme. *Hikobia*, 14:431-457.

You H.-M., K. Fujiwara, Wu S.J. and Wan X.L. 2001. A preliminary vegetation-ecological study of *Quercus mongolica* forests in China. *J. Phytogeography and Taxonomy*, 49:31-51.

Table 1. Summary table of deciduous broad-leaved forests in warm-temperate China

Group Number		A		B			C		D	E	F
Runing number		1	2	3	4	5	6	7	8	9	10
Number of relevés		12	6	3	4	3	10	6	12	8	16
Average number of species		48	51	36	55	45	60	59	51	49	60
Differential species of *Schisandra pubescens-Quercus aliena* community											
Schisandra pubescens	T2,S,H	V	V	·	·	·	·	·	·	·	·
Rhus verniciflua	T1,T2,S,H	V	V	·	·	·	·	·	·	·	·
Cornus kousa var. *chinensis*	T1,T2,S,H	V	V	·	·	·	·	·	·	·	·
Rubus palmatus	S,H	V	V	·	·	·	·	·	·	·	·
Acer grosseri	T1,T2,S,H	V	IV	·	·	·	·	·	·	·	·
Styrax hemsleyana	T2,S,H	IV	V	·	·	·	·	·	·	·	·
Philadelphus incanus	T2,S,H	IV	V	·	·	·	·	·	·	·	·
Lindera obtusiloba	T2,S,H	V	IV	·	·	·	·	·	·	·	·
Viburnum betulifolium	S,H	V	IV	·	·	·	·	·	·	·	·
Quercus glandulifera var. *brevipetiolata*	T1,T2,S,H	IV	IV	·	·	·	·	·	·	·	·
Vitis romanetii	S,H	IV	V	·	·	·	·	·	·	·	·
Abelia biflora	S,H	IV	III	·	·	·	·	·	·	·	IV
Euonymus phellomanes	S,H	IV	III	·	·	·	·	V	·	·	·
Quercus acutissima	T1,T2,S,H	V	III	·	·	·	·	·	·	·	·
Adenophora petiolata	H	III	IV	·	·	·	·	·	·	·	·
Fragaria chinensis	H	III	V	·	·	·	·	·	·	·	·
Pinus armandii	T1,T2,S,H	III	V	·	·	·	·	·	·	·	·
Pteridium aquilinum var. *latiusculum*	H	III	V	·	·	·	·	·	+	I	I
Sorbus alnifolia	T2,S,H	III	III	·	·	·	·	·	·	·	·
Tilia henryana var. *subglabra*	T1,T2,S,H	II	III	·	·	·	·	·	·	·	·
Fraxinus mandshurica	T2,S,H	III	II	·	·	·	·	·	·	·	·
Differential species of submit											
Carex siderosticta	H	IV	I	·	·	·	·	·	·	·	II
Malus prunifolia	S,H	III	I	·	·	·	·	·	·	·	·
Pyrola rotundifolia	S	III	I	·	·	·	·	·	·	·	I
Lilium pumilum	H	III	I	·	·	·	+	·	·	·	·
Lespedeza buergeri	S,H	III	·	·	·	·	·	·	·	·	I
Sorbus folgneri	T2,S,H	III	·	·	·	·	·	·	·	·	·
Acer griseum	T1,T2,S,H	III	·	·	·	·	·	·	·	·	·
Prunus dielsiana	T2,S,H	III	·	·	·	·	·	·	+	·	·
Euonymus lawsonii var. *salicifolius*	S,H	III	·	·	·	·	·	·	·	·	·
Cacalia ambigua	S,H	III	I	·	·	·	·	·	·	·	·
Acer mono	T1,T2,S,H	II	·	·	3	·	·	·	·	·	·
Styrax japonicus	S,H	+	III	·	·	·	·	·	·	·	·
Rubus trianthus	S,H	·	III	·	·	·	·	·	·	·	·
Differential species of *Quercus variabilis -Quercus aliena* community											
Quercus variabilis	T1,T2,S,H	I	II	3	4	3	·	·	·	·	·
Cotinus coggygria var. *pubescens*	T1,T2,S,H	·	·	3	4	1	·	·	·	·	·
Vitis amurensis	H	·	·	1	3	3	+	·	·	·	·
Schisandra sphenanthera	S,H	·	·	2	4	2	·	·	·	·	·
Rhamnus davurica	S,H	·	·	2	3	2	·	·	·	·	·
Clematis florida	S,H	·	·	2	4	3	·	·	·	·	·
Clematis obtusidentata	H	·	·	2	2	1	·	·	·	·	·
Smilax sieboldii	S,H	·	·	·	4	3	·	·	·	·	·
Prunus davidiana	T2,S	·	·	·	3	2	·	·	·	·	·
Asparagus schoberioides	H	·	·	·	2	3	·	·	·	·	·
Vitex negundo	S,H	·	·	·	2	3	·	·	·	·	·

Continue Table 1

Differential species of subunit											
Viburnum mongolicum	T2,S,H	·	·	3	4	·	·	·	·	II	II
Rhamnus rugulosa	T2,S,H	·	·	2	2	·	·	·	·	·	·
Rhododendron molle	S,H	·	·	1	4	·	·	·	·	·	·
Allium anisopodium	H	·	·	3	3	·	·	·	·	·	·
Atractylodes macrocephala	H	·	·	3	4	·	·	·	·	·	·
Crataegus cuneata	T2,S,H	·	·	3	3	·	·	·	·	·	·
Syringa microphylla	S,H	·	·	2	2	·	·	·	·	·	·
Sporobolus indicus	H	·	·	2	3	·	·	·	·	·	·
Zelkova sinica	T1,S,H	·	·	1	3	·	·	·	·	·	·
Rhus potaninii	S,H	·	·	·	3	1	+	·	+	·	·
Lilium concolor	H	·	·	·	3	·	·	·	·	·	·
Spiraea hirsuta	S,H	·	·	·	3	·	·	·	·	·	·
Adenophora tetraphylla	H	·	·	·	2	·	·	·	·	·	·
Aster scaber	H	·	·	·	2	·	·	·	·	·	·
Styrax obassia	S,H	·	·	·	2	1	·	·	·	·	·
Rabdosia inflexa	H	·	·	·	1	3	·	·	·	·	·
Rubus parvifolius	T1,S,H	·	·	·	·	3	·	·	·	·	·
Artemisia shangnanensis	H	·	·	·	·	3	·	·	·	·	·
Aconitum henryi	S,H	·	·	·	·	3	·	·	·	·	·
Diospyros lotus	T2,S,H	·	I	·	·	3	·	·	·	·	·
Parthenocissus himalayana	H	·	·	·	·	3	·	·	·	·	·
Akebia trifoliata	H	·	·	·	·	2	·	·	·	·	·
Amorpha fruticosa	S	·	·	·	·	2	·	·	·	·	·
Juglans regia	S	·	·	·	·	2	·	·	·	·	·
Celtis biondii	S	·	·	·	·	2	·	·	·	·	·
Differential species of higher unit											
Forsythia suspensa	T2,S,H	V	V	3	4	1	·	·	·	·	·
Quercus aliena	T1,T2,S,H	IV	V	3	4	·	II	·	·	·	·
Carpinus turczaninowii	T1,T2,S,H	V	V	3	4	·	·	·	·	·	·
Carex subpediformis	H	V	V	3	1	·	·	·	·	·	·
Lespedeza formosa	S,H	IV	V	·	3	2	·	·	·	·	·
Differential species of *Pyrus betulaefolia-Quercus liaotungensis* community											
Pyrus betulaefolia	T1,T2,S,H	·	·	·	·	·	III	V	II	·	·
Ostryopsis davidiana	S,H	·	·	·	·	·	V	III	I	·	·
Carpesium cernuum	H	+	IV	·	·	·	IV	V	·	·	·
Cerasus polytricha	S,H	·	·	·	·	·	IV	V	I	·	·
Prunus davidiana	T2,S,H	·	·	·	·	·	IV	III	I	·	·
Differential species of subunit											
Ajuga ciliata	H	·	I	·	·	·	IV	·	·	·	·
Adenophora elata	H	+	·	·	·	·	III	·	·	·	·
Euphorbia esula	H	+	·	·	·	·	III	·	I	·	·
Berberis brachypoda	S,H	·	·	·	·	·	·	V	II	·	·
Rubus parvifolius	S,H	·	·	·	·	·	+	V	+	·	·
Acanthopanax setchuensis	S,H	·	·	·	·	·	·	IV	·	·	·
Caragana microphylla	S,H	·	·	·	·	·	·	IV	·	·	·
Acer stenolobum	T1,T2,S,H	·	·	·	·	·	·	III	·	·	·
Taraxacum mongolicum	H	·	·	·	·	·	I	III	+	·	·
Ulmus macrocarpa	T1,T2,S,H	·	·	·	·	·	·	III	·	·	+
Differential species of *Rosa hugonis-Quercus liaotungensis* community											
Rosa hugonis	T2,S,H	·	·	·	·	·	I	·	V	·	·
Thalictrum foetidum	S,H	·	·	·	·	·	·	·	V	·	·
Aconitum sungpanense	S,H	·	·	·	·	·	+	·	IV	·	·
Corylus heterophylla	S,H	·	·	·	1	·	I	·	IV	·	·
Epimedium brevicornu	H	+	·	·	·	·	·	·	III	·	·
Differential species of *Picea meyeri-Quercus liaotungensis* community											
Picea meyeri	T1,T2,S,H	·	·	·	·	·	+	·	·	IV	·
Ribes burejense	S,H	·	·	·	·	·	·	·	·	IV	·
Achnatherum sibiricum	H	·	·	·	·	·	+	·	·	IV	+
Cardamine leucantha	H	·	·	·	·	·	·	·	·	IV	+
Clematis macropetale	S,H	·	·	·	·	·	·	·	·	III	·
Chenopodium glaucum	H	·	·	·	·	·	·	·	·	III	I

Continue Table 1

Differential species of *Acer truncatum-Quercus liaotungensis* community											
Acer truncatum	T1,T2,S,H	·	·	·	·	·	·	·	+	·	V
Rhamnus utilis	S,H	·	·	·	·	·	I	·	·	·	V
Clematis brevicaudata	S,H	·	·	·	·	·	II	·	·	·	V
Saussurea nivea	H	·	·	·	·	·	·	·	·	·	IV
Betula davurica	T1,T2,S	·	·	·	·	·	·	·	·	I	IV
Syringa villosa	T2,S,H	·	·	·	·	·	·	·	·	·	IV
Carex rigescens	H	·	·	·	·	·	·	·	·	·	IV
Plectranthus glaucocalyx	H	·	·	·	·	·	·	·	·	·	IV
Rumex acetosa	H	·	·	·	·	·	·	·	·	·	IV
Deutzia parviflora	S,H	·	·	·	·	·	·	·	·	·	III
Adenophora divaricata	H	·	·	·	·	·	·	·	·	·	III
Duchesnea indica	H	·	·	·	·	·	·	·	·	·	III
Doellingeria scaber	H	·	·	·	·	·	·	·	·	I	III
Dracocephalum moldavica	H	·	·	·	·	·	I	·	·	·	III
Aconitum kusnezoffii	H	·	·	·	·	·	·	III	·	·	III
Differential species of higher unit											
Quercus liaotungensis	T1,T2,S,H	·	·	·	·	·	V	V	V	V	V
Carex lanceolata	H	·	·	·	1	·	V	V	V	V	III
Lespedeza bicolor	S,H	·	·	1	·	·	III	III	V	IV	IV
Bupleurum chinensis	H	·	·	·	·	·	III	I	II	II	IV
Artemisia annua	H	·	·	·	·	·	IV	II	III	III	IV
Agrimonia pilosa	H	·	I	·	·	·	II	II	II	II	V
Populus davidiana	T1,T2,S,H	·	·	·	·	·	+	II	II	II	II
Cotoneaster submultiflorus	T2,S,H	·	·	1	1	·	III	II	III	IV	·
Crataegus kensuensis	T2,S,H	·	·	·	·	·	·	III	V	IV	I
Corylus mandshurica	T2,S,H	·	·	·	·	·	II	·	III	IV	IV
Cotoneaster acutifolius	T2,S,H	·	·	·	·	·	II	·	II	III	I
Acer ginnala	T1,T2,S,H	·	·	·	·	·	IV	V	·	IV	·
Betula platyphylla	T1,T2,S,H	·	·	·	·	·	II	·	·	IV	IV
Viburnum schensianum	S,H	·	·	·	·	·	III	IV	II	I	·
Syringa pekinensis	T2,S,H	·	·	·	·	·	·	V	·	·	III
Rosa acicularis	S,H	·	·	·	·	·	·	·	III	V	V
Companions of *Quercus aliena* and *Q. liatungensis* forests											
Deyeuxia arundinacea	H	V	IV	3	3	1	IV	V	V	III	V
Aster ageratoides	H	IV	III	2	3	1	V	V	III	III	IV
Adenophora polyantha	H	IV	IV	3	2	·	II	·	III	III	II
Adenophora trachelioides	H	III	I	3	4	2	·	IV	+	III	II
Dendranthema indicum	H	IV	V	·	·	·	III	II	III	IV	IV
Dioscorea nipponica	S,H	IV	IV	·	4	·	IV	V	III	·	V
Leibnitzia anandria	H	·	I	2	2	·	V	II	III	II	III
Phlomis umbrosa	H	III	IV	·	·	·	II	·	III	IV	III
Polygonatum odoratum	H	III	IV	2	3	1	III	IV	V	V	V
Polygonatum sibiricum	H	IV	II	1	2	2	II	III	IV	III	·
Rubia cordifolia	H	II	II	3	4	3	III	II	III	V	III
Prunus sibirica	T1,T2,S,H	II	·	2	1	2	+	II	+	II	·
Spiraea pubescens	S,H	IV	V	3	1	1	V	V	V	V	V

Location of relevés Groups:

A: Bao Tian Man Nature Preservation Zone in Nan Yang City of Henan Province

B: Yun Tai Mountain in Jiao Zuo City of Henan Province

C: Ma Lan village and Nan Ni Wan village in Shaanxi Province

D: Pang Tong mountain in Gansu Province

E: Pang Quan Gou Preservation Zone in Jiao Cheng City of Shanxi Province

F: Ling Mountain of Beijing

3) Deciduous *Quercus* and *Fagus* forests in Asia

Kazue Fujiwara (*Institute of Environmental Science and Technology, Yokohama National University, Yokoham, Japan)*
You Hai-Mei (*Institute of City and Environment, Xuzhou Normal University, Xuzhou, China*)
Tang Qiang, Atsuko Harada (*Institute of Environmental Science and Technology, Yokohama National University, Yokohama, Japan)*
Zheng-Xiang Wang (*University of Hubei, Wuhan, China*)
Lin Wang (*Institute of Forestry, Beijing, China*)

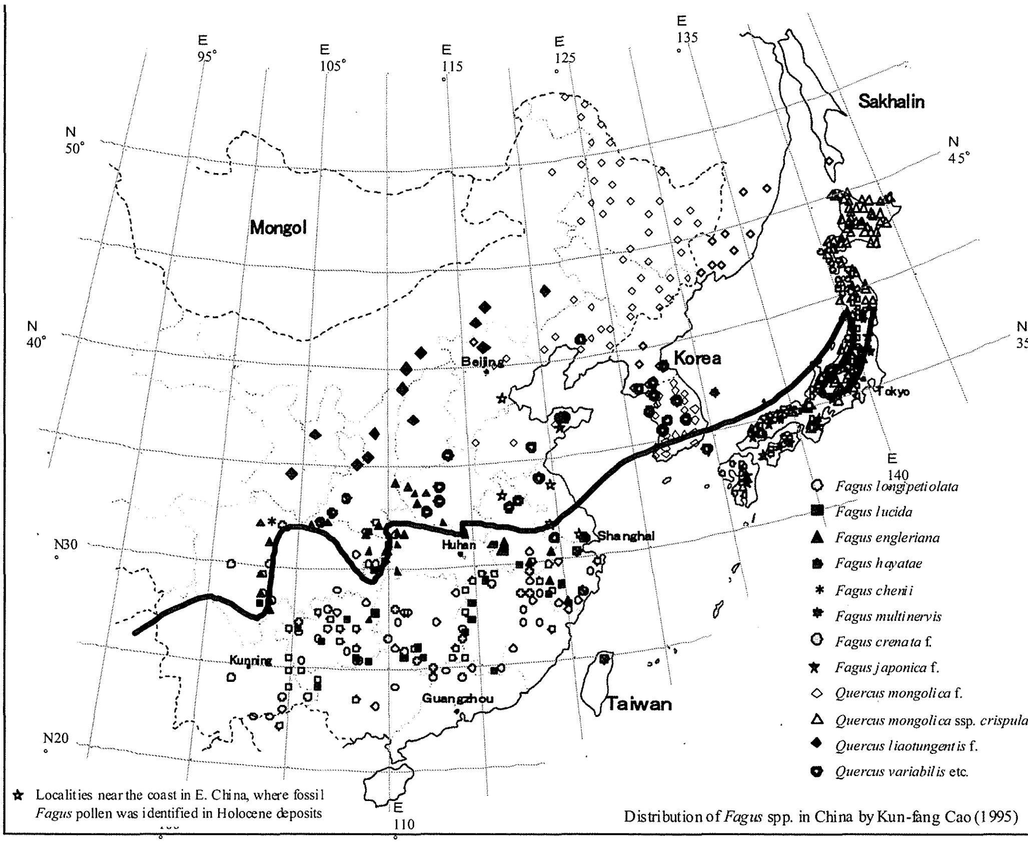
Abstract

Field data for *Fagus* and deciduous *Quercus* forests were compared in a phytosociological summary table in order to identify common species and species groups. In all, 4494 releves were compared, in a table that shows the species composition of *Fagus* and deciduous *Quercus* forests in China, Korea, the Russian Far East and Japan. These groups correspond to characteristic environmental situations: ① *Fagus* forests in China occur above ca 1600m in the Evergreen Broad-Leaved Forests region because of moisture, and their species composition is unique in Asia; ② Northern *Quercus* forests have two types in cool-temperate China (Manchuria) and the Russian Far East, namely *Q. mongolica* forests and *Q. liaotungensis* forests; ③ *Q. Liaotungensis* forests occur in drier conditions and at lower temperature in spring than do the *Q. mongolica* forests; ④ *Q. mongolica* forests occur in northeastern China, the Russian Far East, and also in Korea; ⑤ *Q. lioatungensis* forests occur in middle northern China and at higher elevations around Beijing; ⑥ Common Asian *Quercus* species, such as *Q. variabilis*, *Q. aliena* and *Q. serrata* s.l., occur between the evergreen broad-leaved forest region and the *Q. mongolica* forest area; the species composition is similar in China, Korea and Japan; ⑦ *Fagus* forest in Korea is very unique and only one species occurs, on Ulreung Do island; the species composition is similar to that of Japanese *Fagus* forests; ⑧ *Fagus* forests in Japan are of two types, influenced by deep winter snow on the Japan Sea side and by shallow or lack lack of snow on the Pacific side. In the Integrated Vegetation Map, *Quercus mongolica* forest, *Fagus crenata* forest and *Quercus* forest in Japan are shown as part of the legend item for Summergreen Deciduous Forests; *Q. liaotungensis* forest is included under Scrub with other *Quercus* forests.

Introduction

Deciduous forests in East Asia are mainly *Quercus* and *Fagus* forests in the temperate zone. Six species of *Fagus* occur and four *Fagus* forest communities are recognized in China, occurring on mountains, especially in the evergreen broad-leaved forest region. Some *Fagus* forests occur surrounded above and below by evergreen broad-leaved forest (1600m s.l.), in foggy areas but on slopes that provide sufficient soil drainage. Such forests thus constitute a *Fagus* forest belt, as at Fanjinshan in Guizhou Province. Sometimes *Fagus* forest occurs as patches on ridges, summits or slopes (e.g. Manshan in Guangxi Province and Bao-Tien-Man Nature Reserve in Henan Province). On the other hand, only one unique species, *Fagus multinervis*, occurs and composes *Fagus* forest in Korea, on Ulreung-Do island. In the Japanese Archipelago, two *Fagus* species occur and have potentiality wide habitats because of deep snow accumulation (0.5 to more than 3m sometimes) and high humidity. Most of the *Fagus* forest has disappeared and been replaced by conifer plantations (as forestry) and development, but some places are still protected, as World Natural Heritage, scientific forests, nature preserves, national park, and so on.

The deciduous *Quercus* forests have wider ranges than do the *Fagus* forests, in Asia as well as on other continents. Deciduous *Quercus* species can tolerate lower temperatures, drier climates and human impacts such as cutting. The deciduous *Quercus* forests correspond to climate types: *Q. mongolica* and *Q. crispula* forests in the cool-temperate zone, and *Q. serrata*, *Q. acutissima*, *Q. variabilis*, *Q. dentata*, *Q. aliena*, and others in the warm-temperate zone. Especially in China, about 20 species occur from the temperate zone well into the subtropical evergreen forest zone, sometimes due to human impacts. Species similar to *Q. serrata*, *Q. acutissima*, *Q. variabilis*, *Q. dentata*, and *Q. aliena* occur at lower elevations, and *Q. mongolica*



occurs at higher elevation (due to its greater cold tolerance), but these all may mix in forests greatly disturbed by human activity. These *Quercus* species are similar in Japan except for *Q. mongolica*, which corresponds to *Q. crispula* (former name: *Q. mongolica* var. *grosseserrata*). *Quercus liaotungensis* can tolerate lower temperatures and drier conditions than can *Q. mongolica*. It occurs in mid-western China and at higher elevation than *Q. mongolica* where the two are contiguous.

Methodology

The *Fagus* and deciduous *Quercus* forests were surveyed phytosociological, by the Braun-Blanquet (1964; cf Fujiwara 1987) method, in China and the Russian Far East in 2004-2007. Then all the field data (releve samples) were compared in a large matrix containing original old data and published data (see references). The result is shown in Table 1 and Figure 1-2.

Results

The following communities could be recognized.

1. *Fagus* forests in China (1-4 in Table1)
   In China *Fagus* is recognized as having five species (Chinese Flora Editing Committee 1998). *Fagus* forests in China were classified into four associations: a Sinarundinariao bashersuto-Fagetum lucidae, a Sinarundinariao chungii-Fagetum lucidae, a Sinarundinariao nitido-Fagetum lucidae, and a Fagetum engleriano-lucidae (Wang Z.-X. and Fujiwara 2003a,b). All occur within the evergreen broad-leaved forest region (Figure 1), mostly at 1330-1980m in low mountains of Henan, Hubei, Hunan, Guizhou and Guangxi. Sometimes patches of *Fagus* forest occur surrounded by evergreen broad-leaved forest. These associations have many evergreen species, such as *Quercus gracilis*, *Q. multinervis*, *Camellia cuspidata*, *Q. oxymoron*, and *Illicium simonii*. We also got data from *F. hayatae* forest in Zhejiang, which has more species common to Japan, such as *Lyonia ovalifolia, Hydrangea paniculata, Clethra barvinervis, Cornus kousa*, and *Ardisia japonica*.

2. *Fagus* and *Quercus* forests in Japan and Korea, *Quercus variabilis* forest in China (5-30 in Tab. 1)
   Only *Fagus multinervis* occurs in Korea, on Ulreung-Do island (Kim J.-U. et YimY.-J. 1986). This Forest has many endemic species, such as *Fagus multinervis, Acer takesimense, A.*

okamotoanum, Prunus takesimensis, and *Viola takesimana*; it also, however, has species common with Japan, such as S*asa crilensis, Viburnum furcatum, Hydrangea petiolaris*, and *Q. crispula. Fagus* forests in Japan are of two types, occurring in deep snow on the Japan Sea side (Saso krilensis-Fagion crenatae) and under drier winter conditions on the Pacific side (Sasomorpho-Fagion crenatae). *Fagus crenata* forest on the Japan Sea side has species common with Ulreung-Do (Tab. 1). On the Japan Sea side there are evergreen shrubs species such as *Ilex crenata* var. paludosa, *I. leucopoda, Aucuba japonica* var. *borealis,* and *Cephalotaxus harringtonia* var. *nana*, along with evergreen *Sasa kurilensis*, which tolerate cold winter temperatures under accumulated snow. On the other hand, *Fagus* forest on the Pacific side has species common with *Fagus hayatae* forests of China, as described on the previous page. *Fagus* forests also have species common with *Q. crispula* forests in the higher elevations or latitudes in Japan. These forests are quite different from the *Fagus* forests in China that occur within evergreen broad-leaved forests. Japan is surrounded by the sea, so moisture is always more available and helps explain the good development of *Fagus* forest and sometimes the mixing with *Quercus crispula*. *Fagus* forests had been well studied before, for example by Sasaki (1970), by Hukusima et al. (1995, 2000), and others.

Fagus crenata forest in Honshu has a species composition similar to that of *Quercus variabilis* and *Q. acutissima* in China & Korea (which the Chinese call their warm-temperate zone). *Viburnum dilatatum, Lindera obutusiloba, Stephanandra incisa*, etc. occur, but *Q. variabilis* and *Q. aliena* forests in west-central China have different species composition (see 4).

3. *Quercus aliena* forests and *Quercus liaotungensis* forests (31-46 in Tab. 1)

Quercus liaotungensis forests occur from Inner Mongolia to an area above 1000m north of Beijing and from Hebei to Gansu Province in the west. As a species, *Quercus liaotungensis* itself also ranges into the

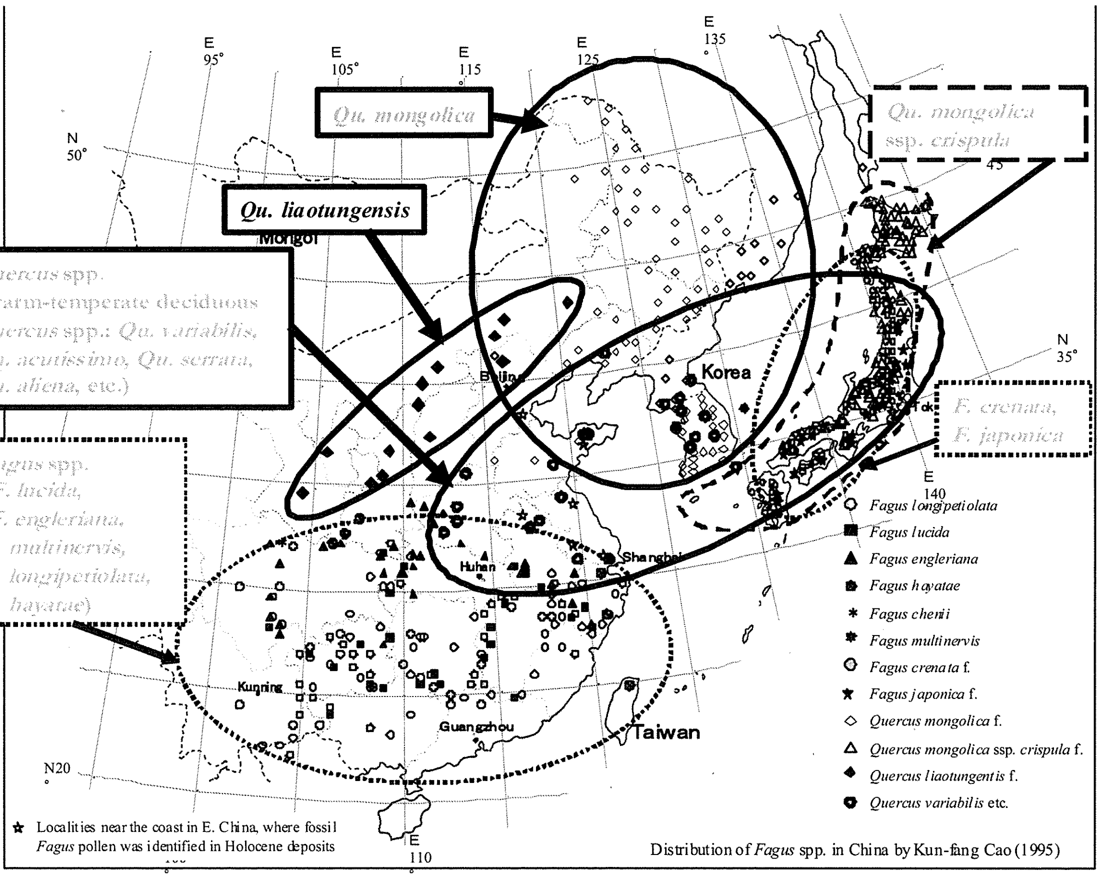


Fig. 2 Species composition group of *Fagus* and *Quercus* forests in Asia based on Table 1.

Russian Far East (near Vladivostok). Q*uercus liaotungensis* forests characteristically have *Ostryopsis davidiana, Spiraea pubescens, Cotoneaster multiflorus, C. acutifolius, C. zabelii, Lonicera ferdinandii, Rosa xanthina, Rosa hugonis, Abelia biflora*, and *Viburnum schensianum* in the shrub layer, and

Prunus sibirica, Prunus tomentosa and *Crataegus kensuensis* in the tree layer. The forests are not tall, at 10 to 15m, because of the dry climate (400-600mm rainfall annually), cold winter temperatures (reaching -30 to -40°C) and short growing season, from late May to August. The forest floor has many grassland and meadow species, such as *Carex lanceolata, Polygonatum odoratum* sl., *Aster scaber, A. ageratoides* sl., *Smilax stans, Atractylodes lancea, Tipularia szechuanica, Polygonatum sibiricum*, and *Dioscorea nipponica*. These are similar to the species of *Miscanthus* grassland and forest floor of secondary forests in Japan.

4. *Quercus mongolica* forests (47-62 in Tab. 1)

Quercus mongolica forests are well described by Krestov et al. (2006), Wang et al. (2006), and Wang (2007). *Quercus mongolica* forests were summarized into a Quercetea mongolicae with two orders. The order Tilio amurensis-Pinetalia koraiensis has sub-units Abieti nephrolepidis-Pinion koraiensis, Abieti nephrolepidis-Pineon koraiensis (six associations, one community), Brachybotryo-Acerenon mono (six communities) and Corylo heterophyllae-Quercion mongolicae (two associations, one community); the other order, Aceri-pseudosieboldiani-Quercetalia mongolicae, is in Korea and has three alliances.

The main habitat of *Quercus mongolica* forest is in northeastern Asia, including the Russian Far East, Manchuria and as far south as around Beijing. *Quercus mongolica* forests have two types of forest composition. One type is a mixture of *Quercus mongolica* and the evergreen conifer *Pinus koraiensis*; this type requires moisture and is mostly natural forest. Occurring also in the tree layer may also be *Acanthopanax senticosus, Euonymus pauciflorus, Tilia mandshurica, Populus davidiana, Betula platyphylla Ulmus macrocarpa Acer ginnala*, *Fraxinus mandshurica*, etc. In the shrub layer one can see *Philadelphus schrenkii, Deutzia glabrata, Viburnum sargentii, Ulmus laciniata, Acer tegmentosum*, etc. The forest floor has many meadow species, such as *Polygonatum involucratum, Carex ussuriensis, Phellodendron amurense*, and *Cardamine leucantha.* These forest-floor species are common in *Fagus crenata* forests in Japan. The other type of *Quercus mongolica* forest is drier and includes secondary forests and forests on steep slopes. Mostly grassland and drier meadow species occur in this forest floor, such as *Viburnum burejaeticum, Carex pilosa, Adenocaulon himalaicum, Saussurea discolor, Aconitum raddeanum, Stellaria radians, Glycine soja, Brachybotrys paridiformis, Rubia sylvatica*, and *Carex callitrichos*, with *Lespedeza bicolor* in the shrub layer. *Lespedeza bicolor* can be especially dominant in the forest after fire.

Quercus mongolica forests and *Quercus liaotungensis* forests occur over the cool-temperate parts of northern Asia. In the middle of China, on the other hand, there are so-called warm-temperate (in the Chinese sense) *Quercus* forests with *Quercus variabilis* and *Q. acutissima*. *Quercus mongolica* forests and *Quercus liaotungensis* forests can be seen above 1000m. These forests have species in common, such as *Malus baccata, Lonicera chrysantha Berberis amurensis Rhamnus parvifolia Euonymus alatus, Corylus heterophylla Corylus mandshurica Fraxinus rhynchophylla, Acer ginnala, Euonymus alatus Rhamnus parvifolia* in the shrub layer, and *Veratrum nigrum, Sedum aizoon* and *Dioscorea nipponica* in the herb layer.

5. Querco mongolicae-Betuletea (63 in Tab. 1)

Ermakov (1997) described *Betula davurica* and *Betula davurica-Quercus mongolica* forests summarized into a Querco mongolicae-Betuletea davuricae. It is difficult to divide two types (see 3) into two classes. Krestov et al. (2006) discussed dividing *Q. mongolica* forests into two classes. Afterward Wang and Fujiwara (2006) tried to clarify these two types and understood that *Quercus mongolica* forests in the table of Ermakov (2006) represented wooded savanna (scattered woods in grassland or meadow). The tree and shrub species showed themselves to be different when compared in the same table (see Tab. 1). Some of the grassland species are common in *Quercus mongolica* forests, but still these species belong to the grassland, such as *Fragaria orientalis, Synurus deltoids, Paeonia lactiflora, Vicia pseudo-orobus, Aster tataricus*, *Sedum aizoon*, etc. Many species occur in meadows, such as *Trifolium lupinaster, Chrysanthemum Dendranthema zawadskii, Galium boreale, Astragalus membranaceus, Spiraea media, Artemisia*

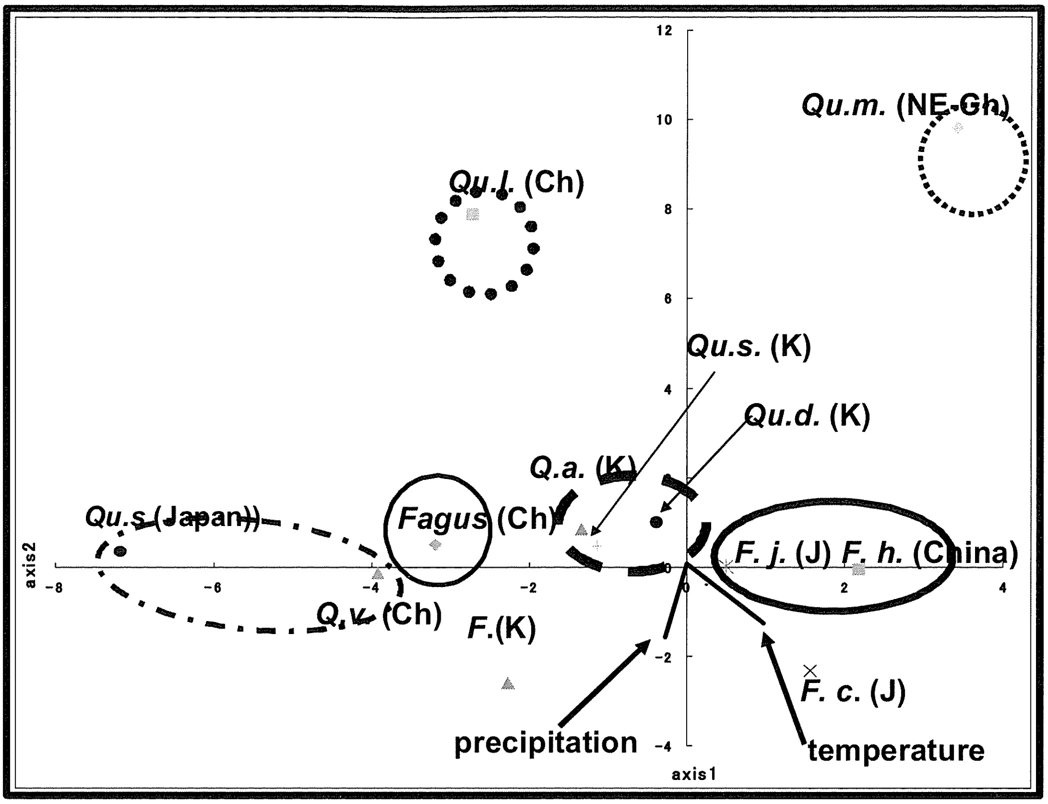


Fig. 3 Environmental Factors for Quercus and Fagus forests in Asia by CCA analysis.

tanacetifolia, Saussurea elongata, Pulsatilla patens, Carex amgunensis, Scorzonera radiata, Elymus gmelinii, Poa botryoides, Aster alpinus, Adenophora tricuspidata, Anemonastrum crinitum, Thalictrum appendiculatum, Lilium dauricum, etc.

References (numbers are shown in table 1)

1. Ammer, U., U. Fischer, and Chen C. G. 2003. Degradationsgefahren und Renaturierung durch Wiederbewaldung in Lösslandschaften der Nordwestchinesischen Provinz Shaanxi/VR China (final report of BMBF project 0339743 to the German Ministry of Science and Technology and the Shaanxi State Education Commission, Freising, 255pp.
2. Braun-Blanquet, J. 1964. *Pflanzensoziologie, Grundzuege der Vegetationskunde*. 3rd edition. Springer-Verlag, Wien. 631pp.
3. Cao K.-F. 1995. *Fagus* dominance in Chinese montane forest: natural regeneration of *Fagus lucida* and *Fagus hayatae* var. *pashanica*. Doctoral thesis, Wageningen Agricultural University, Wageningen. 116pp.
4. Cao K.-F. and R. Peters 1997. Species diversity of Chinese beech forest in relation to warmth and climatic disturbance. *Ecol. Res*., 12:175-189.
5. Chang Y.-T. and Huang C.-C. 1988. Notes on Fagaceae (2). *Acta Phytotaxonomica Sinica*, 26(2): 111-119 (in Chinese with English abstract).
6. Ermakov, N., J. Dring, and J. Rodwell 2000. Classification of continental hemi-boreal forests of North Asia. *Braun-Blanquetia*, 28:1-131.
7. Fang J.-Y. and K. Yoda 1989. Climate and vegetation in China. 2: Distribution of main vegetation types and thermal climate. *Ecol. Res*., 4:71-83.
8. Fischer, A., U. Schmidt, C. Cungen, and U. Ammer 2006. Case study –Sino-German research project on ecological restoration and soil erosion control on the northwestern China Loess Plateau. Ecological restoration in loess plateau. KRESEC Ecological Book Series 3, on Land Resource Management and Ecological Restoration in the Loess Plateau. 26pp.

9. Fujiwara, K. 1987. Aims and methods of phytosociology or "vegetation science". In: *Plant ecology and taxonomy or the memory of Dr. Satoshi Nakanishi*, pp. 607-628. Kobe Geobotanical Society, Kobe.
10. Hanazawa, M. 2006. Vegetation ecology of secondary Quercus serrata forests in southern Kanto (eastern Japan): species compositeon and vegetation distributeion in the Tama and Miura Hills. Master. Thesis. Yokohama National University. 58pp .
11. Hoshino, Y. 1998. Phytosociological studies of Quercus mongolica var. grosseserrata forest in Japan. Bulletin of Faculty of Agriculture Tokyo University of Agriculture and Technology 32, 99pp. Tokyo.
12. Hukusima, T. , H. Takasuna, T. Matsui, T. Nishio, Y. Kyan, and Y. Tsunetomi 1995. New phytosociological classification of beech forests in Japan. *Japanese J. Ecology*, 45:79-98.
13. Hukusima, T., T. Nishio, and T. Matsui 2000. Floristic composition and differentiation of the association of beech forests in Japan. *Hikobia*, 13:335-353.
14. Kim J.-U. and Yim Y.-J. 1986. Classification of forest vegetation of Seonun-san area, southwestern Korea. *Korean J. Ecology*, 9(4):209-223.
15. Kim J. W. 1992. Vegetation of northeast Asia on the syntaxonomy and syngeography of the oak and beech forest. Ph. D. Thesis. University of Vienna. 314pp.
16. Kim S.-D., M. Kimura and Yim Y.-J. 1986. Phytosociological studies on the beech (*Fagus multinervis* Nakai) forest and the pine (*Pinus parviflora* S. et Z.) forest of Ulreung Island, Korea. *Korean J. Botany*, 29(1):53-65.
17. Kolbek, J., I. Jarolímek, and M. Valachovič 2003. Forest vegetation of the northern Korean Peninsula. In: *Forest Vegetation of Northeast Asia* (J. Kolbek, M. Šrůtek, and E. O. Box, eds.), pp 263-361. Kluwer Academic Publisher.
18. Kolbek , J., M. Valachovič, N. Ermakov, and Z. Neuhäuslová 2003. Comparison of forest syntaxa and types in northeast Asia. In: *Forest Vegetation of Northeast Asia* (J. Kolbek, M. Šrůtek, and E. O. Box, eds.), pp 409-462. Kluwer Academic Publisher.
19. Krestov, P. V. 2003. Vegetation of Easternmost Russia (Russian Far East). In: *Forest Vegetation of Northeast Asia* (J. Kolbek, M. Šrůtek, and E. O. Box, eds.), pp 93-180. Kluwer Academic Publisher.
20. Krestov, P. V., Song J.-S., Y. Nakamura, and V. P. Verkhola 2006. A phytosociological survey of the deciduous temperate forests of mainland Northeast Asia. *Phytocoenologia*, 36(1):77-150.
21. Menitsky, Yu. L. 2005. *Oaks of Asia*. Science Publishers, Inc. USA. 549pp.
22. Miyawaki, A. (ed.), 1980-89. *Nippon Shokusei Shi* [Vegetation of Japan]. 10 vols, each about 400-700pp plus vegetation tables and color maps (in Japanese, with German or English summary). Shibundo, Tokyo.
23. Peters, R. 1992. Ecology of beech forest in the northern hemisphere. Doctoral thesis, Landbouwuniversitaet, Dordrecht. 122pp.
24. Qian H., P. V. Krestov, Fu P.-Y., Wang Q.-Li., Song J.-S. and Ch. Chourmouzis 2003. Phytogeography of Northeast Asia. In: *Forest Vegetation of Northeast Asia* (J. Kolbek, M. Šrůtek, and E. O. Box, eds.), pp 51-91. Kluwer Academic Publisher.
25. Qian H., Yuan X.-Y. and Chou Y.-L. 2003. Forest vegetation of northern Japan and the southern Kurils. In: *Forest Vegetation of Northeast Asia* (J. Kolbek, M. Šrůtek, and E. O. Box, eds.), pp 231-261. Kluwer Academic Publisher.
26. Sasaki, Y. 1970. Versuch zur systematischen und geographischen Gliederung der Japanischen Buchenwaldgesellschaften. *Vegatatio*, 20:214-249.
27. Shimano, K. 1999. [The effects of snow upon Japan Sea-type beech forest.] *J. Phytogeogr. Taxon.* 47:97-106 (in Japanese with English abstract).
28. Song J.-S. 2001. Phytosociological study of the oak (*Quercus* spp.) forests on Mts. Kaya, Bisul, Unmun and Kaji in southern Kyongpook Province. *Korean J. Ecol.*, 24(1):9-18.
29. Song J.-S., Roh K.-S., Chung H.-S., Song S.-D., K. Ohno, and Y. Mochida 1999a. Phytosociology of the *Quercus* spp. forests on Mts. Palgong, Kumo and Hwangak in the city areas of Taegu, Kumi and Kimchon, Kyungpook Province, Korea. *Korean J. Ecol.*, 13(3):220-233.
30. Song J.-.S, Roh K.-S., Chung W.-S., Song S.-D., K. Ohno, and Y. Mochida 1999b. Phytosociological study of the forest vegetation in the mountainous areas of the northern part,

Kyungpook Province, using the methodology of physiognomy and numerical syntaxonomy. *Korean J. Ecol.*, 22(5): 241-254.

31. Suzuki, S. 2002. A phytosociological study of summergreen broad-leaved forests in Japan. Doctoral thesis. Yokohama National University. 139pp.
32. Suzuki, S., and A. Miyawaki 2006. Comparison of *Quercus* forests in western Japan and eastern China. *Folia Botanical Studies*, 22:48-501.
33. Tang, Q., Fujiwara, K. and You, H.-M., 2008. 2. Warm temperate deciduous forest: Phytosociological study on deciduous broad-leaved forests in warm temperate zone of China I: Characteristics of different plant communities. Report for Research Project, Grant-In-Aid for Scientific Research (16255003). pp. 00-00.
34. Wang L. 2007: A vegetation-ecological study of deciduous broad leaved forests in Heilongjiang Province, China. Doctoral Thesis, Yokohama National University. 68pp.
35. Wang L., K. Fujiwara, and You H.-M. 2006: A vegetation-ecological study of deciduous broad-leaved forests in Heilongjiang province, China: species composition, structure, distribution and phytosociological scheme. *Hikobia*, 14:431-457.
36. Wang Z.-X. A vegetation ecologyical study of *Fagus* forests in China. Doctoral Thesis, Yokohama National University. 157pp.
37. Wang Z.-X. and K. Fujiwara 2003a. A preliminary vegetation study of *Fagus* forests in central China: species composition, structure and ecotypes. *J. Phytogeogr. Taxon.*, 51:137-157.
38. Wang Z.-X. and K. Fujiwara 2003b. Phytosociological study of the *Fagus lucida* forests and *Fagus engleriana* forests in China. *J. Phytogeogr. Taxon.*, 53:43-65.
39. Yim, Y.-J., Kim, J.-U., Lee N.-J., Kim Y.-B. and Paek K.-S. 1990. Phytosogiological classification of plant communities on Mt. Halla National Park, Korea. *Korean J. Ecol.*, 13(2):101-130.
40. You H.M. 2001. A vegetation-ecological Study of *Quercus mongolica* forests in China. Doctoral Thesis, Yokohama National University. 67pp.
41. You H.-M., K. Fujiwara and Tang Q. 2008. 1) *Quercus liaotungensis* forest in China. Report for Research Project, Grant-In-Aid for Scientific Research (16255003). pp. 00-00.
42. You H.-M., K. Fujiwara, Wu S.-J. and Wan X.-L. 2001. A preliminary vegetation-ecological study of *Quercus mongolica* forests in China. *J. Phytogeogr. Taxon.*, 49:31-51.

Country name	C	C	C	C	K	J	J	J	J	J	J	J	J	J	J	J	J	J	J	K	K	K	K	K	K	K	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	R	R	R	R	R
Dominat species	F.lu	F.e.	F.lo.	F.h.	F.m.	F.c	F.j	F.c	F.c	F.c	Q.mg	Q.mg	Q.mg	Q.mg	Q.mg	Q.mg Q.s	Q.s	Q.s	Q.mg C.t	Q.mg C.l	C.l Q.s	Q.s Q.v,Q.a	C.spp	Q.m	Q.m	Q.m Q.s	Q.sb Q.v	Q.f,Q.a Q.v	Q.v	Q.v	Q.al	Q.al	Q.l	Q.l Q.al	Q.l	Q.l	Q.l	Q.l	Q.l	Q.l	Q.l	Q.l	Q.l	Q.l	Q.l	Q.l	Q.m	Q.m	Q.m	Q.m	Q.m	Q.m	Q.m Po.u	Q.m	Q.m	Q.m	Q.m	Q.m	Q.m	Q.m	Q.m	Q.m
References	38	38	38	38	15	22	22	22	22	22	22	11,22	11,30	30	11,30	30	10,30	30	11	39	39	16	14	14	14	14	41	41	41	33	33	33	41	41	41	41	41	41	33	33	33	33	41	33	33	41	34	34	34	34	41	34	34	34	41	34	34	20	20	20	20	20
Number of relevés	17	23	3	7	24	432	428	476	1809	12	51	81	138	247	124	226	224	165	7	7	50	18	52	134	145	69	6	6	3	10	10	8	7	6	7	5	34	79	10	6	12	6	10	8	16	17	9	22	18	47	50	55	7	4	32	6	10	116	118	117	96	104
Mean number of species					27	27	35	29	31	34	31	48			46	42	58	49	64	34	35	28	43	43	35	48	43	42	57	46	48	53	50	47	35	44	?	30	60	59	51	30	33	49	60	42	38	52	46	47	49	42	59	35	43	75	54	76	55	51	41	51
Characteristec & differntial species of ass. & differntial species of comn.																																																														
Sinarundinaria chungii	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Symplocos adenopus	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Enkianthus serrulatus	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Illicium simonsii	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Maphonia japonica (Hiiraginanten)	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fagus engleriana	.	IV	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Castanea henryi	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron hypoglaucum	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fagus lucida	V	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Quercus multinervis	V	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hydrangea anomala	III	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ainsliaea henryi	II	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fagus longipetiolata	I	.	3	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ophiorrhiza japonica (Satsumainamori)	I	II	3	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Quercus oxyodon	.	I	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex filicina	+	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cercis chinensis	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aesculus wilsonii	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Toona ciliata	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fagus hayatae	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lindera reflexa	I	I	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Schima superba	I	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acanthopanax evodiaefolius	.	II	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron mariesii	.	II	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fraxinus chinensis	.	II	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Quercus nubium	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carpinus viminea	I	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron latoucheae (Seishika)	I	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eurya rubiginosa var. *atenuata*	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ilex wilsonii	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Magnolia cylindrica	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Litsea coreana var. *sinensis*	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ardisia crenata (Manryou)	II	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	II	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I	.	.
Camellia cuspidata	II	I	3	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pyrola decorata	+	III	2	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Quercus gracilis	.	II	2	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron simsii (Taiwanyamatsutsuji)	+	III	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fagus multinervis	.	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acer takesimense	.	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anemone maxima (Ohsuhamasou)	.	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acer okamotoanum	.	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Prunus takesimensis	.	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tilia insularis	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ligustrum foliosum	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Allium victorialis var. *platyphyllum* (Gyoujaninniku)	.	.	.	.	III	.	.	.	.	+	I	I	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	+
Sasa kurilensis (Chishimazasa)	.	.	.	.	II	.	.	.	IV	III	III	+	II	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paris tetraphylla (Tsukubanesou)	.	.	.	.	.	+	+	I	II	III	I	+	II	+	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ilex crenata var. *paludosa* (Haiinutsuge)	.	.	.	.	.	.	.	.	III	III	II	r	III	III	r	.	.	r	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cephalotaxus harringtonia var. *nana* (Haiinugaya)	.	.	.	.	.	.	.	.	III	IV	I	r	III	III	.	.	.	+	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lindera umbellata ssp. *membranacea* (Ohbakuromoji)	.	.	.	.	.	.	I	+	III	III	+	.	III	III	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tilia japonica (Shinanoki)	.	.	.	.	.	I	.	I	.	III	IV	II	II	I	II	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fagus crenata (Buna)	.	.	.	.	.	V	IV	V	V	V	.	.	II	II	II	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acanthopanax sciadophylloides (Koshiabura)	.	.	.	.	.	II	III	II	IV	IV	I	+	I	III	II	II	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acer japonicum (Hauchiwakaede)	.	.	.	.	.	.	III	II	IV	V	III	I	III	III	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lonicera vidalii (Onihyoutanboku)	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euonymus melananthus (Sawadatsu)	.	.	.	.	.	r	.	+	.	.	.	.	+	r	r	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fraxinus longicuspis (Yamatoaodamo)	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	r	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.
Camellia japonica (Yabutsubaki)	.	.	.	.	.	+	.	r	.	.	.	.	.	+	.	r	I	II	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	I	.	.
Alangium platanifolium var. *trilobum* (Urinoki)	.	.	.	.	.	.	.	.	.	.	.	r	+	r	r	r	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cryptomeria japonica (Sugi)	.	.	.	.	.	r	.	r	.	.	.	.	I	+	.	r	I	+	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helwingia japonica (Hanaikada)	.	I	.	.	.	.	.	I	.	.	.	.	II	+	+	r	II	I	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dryopteris sabaei (Miyamaitachishida)	.	.	.	.	.	.	II	I	I	II	r	.	I	I	r	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex insaniae (Hirobasuge)	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mallotus japonicus (Akamegashiwa)	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	r	I	I	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cremastra appendiculata (Saihairan)	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	r	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paeonia japonica (Yamasyakuyaku)	.	.	.	.	.	r	.	r	.	.	.	.	r	r	r	r	.	r	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	II	.	.	.	.	.
Oplismenus undulatifolius var. *japonicus* (Kochijimizasa)	.	.	.	.	.	.	.	.	.	.	.	.	r	+	r	I	III	II	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aucuba japonica (Aoki)	.	.	.	.	.	r	.	r	.	.	.	.	.	r	.	r	III	I	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ligustrum japonicum (Nezumimochi)	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	r	II	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eurya japonica (Hisakaki)	.	.	.	.	.	.	+	.	.	.	.	.	.	II	r	r	IV	III	V	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fraxinus lanuginosa f. *serrata* (Aodamo)	.	.	.	.	.	III	III	IV	III	III	I	II	III	II	IV	+	r	+	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhus ambigua (Tsutaurushi)	.	.	.	.	.	III	II	II	IV	V	IV	II	IV	II	II	I	+	r	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tripterospermum japonicum (Tsururindou)	.	.	.	.	.	+	+	+	II	III	I	r	III	III	+	+	r	II	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Skimmia japonica var. *intermedia* f. *repens* (Tsurushikimi)	.	.	.	.	.	II	I	II	III	V	III	r	I	I	.	r	r	r	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Corylus sieboldiana (Tsunohashibami)	.	.	.	.	.	.	I	I	II	.	I	r	IV	IV	III	II	I	I	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Magnolia hypoleuca (Hohnoki)	.	.	.	.	.	I	II	I	II	IV	III	I	IV	II	II	I	II	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Prunus grayana (Uwamizuzakura)	.	.	.	.	.	.	II	I	II	I	r	r	IV	III	II	II	II	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lindera umbellata (Kuromoji)	I	II	.	.	.	I	III	III	II	.	.	.	.	II	I	I	III	III	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lyonia ovalifolia sl. (Nejiki rui)	.	II	.	III	.	I	II	+	.	.	.	.	.	II	r	II	+	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hydrangea paniculata (Noriutsugi)	.	.	.	III	.	I	I	II	II	III	III	II	III	II	IV	II	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clethra barbinervis (Ryoubu)	.	.	.	IV	.	IV	IV	IV	III	+	.	.	r	III	IV	II	I	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cacalia auriculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	II	.	.	.	.	.	.	.	.	.	+	II	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	II	.	.	.	r	.	.	.	.	.	I	.	r	II	II
Asiasarum sieboldii (Usubasaishin)	.	.	.	.	.	.	.	r	.	.	.	.	I	+	r	.	.	.	.	V	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vaccinium koreanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	I	.	.	II	I	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anemone asiatica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxalis obtriangulata (Ohyamakatabami)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	I	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron weyrichii (Ontsutsuji)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	r	r	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Maackia fauriei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sasa quelpaertensis (Tannazasa)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asarum maculatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Taxus cuspidata (Ichii)	.	.	.	.	II	.	.	.	.	I	II	+	+	.	.	.	.	.	.	IV	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	II	+
Symplocos chinensis var. *leucocarpa* f. *pilosa* (Sawahutagi)	.	.	.	.	.	.	.	.	.	.	r	.	I	II	II	I	II	+	I	II	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viburnum furcatum (Ookamenoki)	.	.	.	.	II	II	II	II	V	V	IV	+	III	III	III	+	.	.	V	V	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Quercus mongolica ssp. *crispula* (Mizunara)	.	.	.	.	.	III	III	II	II	III	V	V	IV	IV	V	II	.	r	V	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cornus kousa (Ymaboushi)	I	V	I	II	.	I	I	II	I	.	.	.	I	III	I	I	r	II	III	V	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acer koreanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium trachyspermum (Yotsubamugura)	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	r	r	.	.	.	.	.	III	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tripterygium regelii (Kuroduru)	.	.	.	.	.	.	.	+	.	.	r	r	r	r	r	.	.	.	.	.	.	.	I	IV	II	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	r	+	+	.	+
Veratrum japonicum (Syurosou)	.	.	.	.	.	.	.	.	.	.	r	+	r	+	r	+	.	.	.	.	.	.	I	III	+	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Angelica gigas	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	III	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	r	I	I	.	I	.	.	.	.	.	.
Pseudostellaria palibiniana (Higenewachigaisou)	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	+	.	I	III	I	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex humilis (Hosobahikagesuge)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	r	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lespedeza cyrtobotrya (Marubahagi)	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	r	r	.	.	.	.	.	.	I	III	I	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.
Palura paniculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lindera obtusiloba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lespedeza tomentosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	II	IV	.	.	.	.	.	.	.	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.
Ainsliaea acerifolia (Momijihaguma)	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	.	I	II	IV	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Symplocos chinensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	III	II	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	.	.
Rhododendron mucronulatum (Karamurasakitsutsuji)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	I	II	IV	II	.	.	.	.	.	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	+	I	I	+	r
Rhododendron schlippenbachii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	IV	V	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	+	.	.
Euonymus ciliato-dentatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	I	II	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Magnolia sieboldiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	I	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.
Lindera erythrocarpa (Kanakuginoki)	.	.	.	.	.	+	.	.	.	.	.	.	.	r	r	r	r	+	.	II	IV	III	IV	r	I	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fraxinus sieboldiana (Marubaaodamo)	.	.	.	.	.	.	I	+	.	.	r	.	+	II	I	II	I	II	I	.	.	I	II	II	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Quercus serrata (Konara)	.	.	.	.	.	.	I	+	.	.	.	r	II	III	I	IV	V	IV	.	.	IV	IV	II	+	III	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Castanea crenata (Kuri)	.	.	.	.	.	.	I	.	.	.	.	r	III	IV	II	III	III	III	.	.	.	.	I	r	I	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.
Smilax nipponica (Tachishiode)	.	.	.	.	.	.	.	.	.	I	.	.	II	II	+	+	+	I	IV	.	I	III	III	II	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I	.	.
Carpinus tschonoskii (Inushide)	.	.	.	.	.	I	I	II	.	.	.	.	.	II	I	I	II	I	V	III	II	IV	III	r	I	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carpinus laxiflora (Akashide)	.	.	.	.	.	I	II	I	+	+	.	r	+	II	I	II	I	II	.	V	V	II	II	+	II	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Callicarpa japonica (Murasakishikibu)	.	.	.	.	.	+	II	I	+	+	.	r	II	II	I	II	IV	II	V	.	I	.	II	I	I	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dalbergia hupeana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Liquidambar formosana (Huu)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Celtis sinensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	I	IV	2	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ilex cornuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ficus pumila (Ooitabi)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Schisandra sphenanthera	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Atractylodes macrocephala (Oookera)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viola variegata (Huirigenjisumire)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	IV	.	.	.	.	.	.	.	.	II	.	.	I	.	.	III	.	.	.	.	III	I	.	.	.	I	I	.	.	.	r	.	.
Viburnum mongolicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	.	.	II	.	.	.	.	.	.	.	.	.	II	II	II	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crataegus cuneata (Sanzashi)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	+	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sporobolus indicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vitex negundo	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron molle	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pistacia chinensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	V	2	III	I	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Symplocos paniculata (Kurominonishigori)	II	II	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	r	.	.	.	.	.	.	.	.	V	V	1	.	I	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.
Characteristec species of Quercetalia serrato- grosseserratae																																																														
Quercus variabilis (Abemaki)	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	r	r	II	.	.	.	IV	III	.	III	II	IV	III	3	V	I	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viburnum dilatatum (Gamazumi)	.	.	.	.	.	+	I	II	.	.	.	+	III	II	II	III	IV	II	III	.	.	IV	III	+	I	I	I	III	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Smilax china (Sarutoriibara)	.	.	.	.	.	+	.	+	.	.	.	.	II	III	r	II	IV	IV	V	IV	V	IV	+	r	+	+	V	I	3	II	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oplismenus undulatifolius (Kechijimizasa)	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	I	II	III	II	.	I	II	III	IV	3	III	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stephanandra incisa (Kogomeutsugi)	.	.	.	.	.	.	+	I	.	.	.	.	.	r	II	II	III	r	.	.	.	III	III	II	III	IV	V	I	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinus densiflora (Akamatsu)	.	.	.	.	.	.	.	.	.	.	.	.	+	I	+	I	I	II	.	I	I	III	II	II	III	I	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.	.	.	.
Lindera obtusiloba (Dankoubai)	+	II	.	.	.	.	I	.	.	.	.	.	.	II	II	III	+	I	.	.	II	IV	IV	II	IV	V	II	I	.	.	IV	V	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Styrax japonicus (Egonoki)	.	.	.	.	.	I	I	I	.	.	.	.	II	II	+	II	IV	III	.	I	IV	III	II	.	I	II	IV	I	.	.	II	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Quercus acutissima (Kunugi)	[illegible]
Platycarya strobilacea (Nogurumi)	[illegible]
Lespedeza buergeri (Kihagi)	[illegible]
Acer griseum	[illegible]
Prunus dielsiana	[illegible]
Euonymus lawsonii var. *salicifolius*	[illegible]
Philadelphus incanus	[illegible]
Saussurea dutaillyana	[illegible]
Quercus glandulifera var. *brevipetiolata*	[illegible]
Rhus verniciflua (Urushi)	[illegible]
Cornus kousa var. *chinensis*	[illegible]
Rubus palmatus (Nagabamomijiichigo)	[illegible]
Schisandra pubescens (Kematsubusa)	[illegible]
Styrax hemsleyana	[illegible]
Pyrola rotundifolia	[illegible]
Carpinus turczaninovii (Iwashide)	[illegible]
Carex subpediformis	[illegible]
Lespedeza formosa (Taiwanhagi)	[illegible]
Forsythia suspensa (Rengyou)	[illegible]
Rosa omeiensis	[illegible]
Sorbaria kirilowii	[illegible]
Picea wilsonii	[illegible]
Stipa przewalskii	[illegible]
Tilia paucicostata	[illegible]
Berberis dielsiana	[illegible]
Rubus coreanus	[illegible]
Euonymus porphyreus	[illegible]
Lonicera tragophylla	[illegible]
Foresythia giraldana f. *pubescens*	[illegible]
Ligularia veitchiana	[illegible]
Wikstroemia micrantha	[illegible]
Rhus succedanea (Haze)	[illegible]
Quercus aliena (Naragashiwa)	[illegible]
Viburnum betulifolium	[illegible]
Pinus armandii (Amamigoyou)	[illegible]
Euonymus phellomanus	[illegible]
Acer grosseri	[illegible]
Litsea pungens	[illegible]
Ribes graciale	[illegible]
Berchemia sinica	[illegible]
Deutzia grandiflora	[illegible]
Euonymus bungeanus	[illegible]
Crataegus aurantia	[illegible]
Carpinus turczaninovii var. *stipulata*	[illegible]
Tilia mongolica	[illegible]
Lonicera microphylla	[illegible]
Syringa pubescens ssp. *microphylla*	[illegible]
Berberis giraldii	[illegible]
Acanthopanax stuchuensis	[illegible]
Asparagus brachyphyllus	[illegible]
Polygonatum cirrhifolium	[illegible]
Syringa komarowi	[illegible]
Caragana arborescens	[illegible]
Lespedeza juncea	[illegible]
Spiraea hirsuta	[illegible]
Rubus mesogaeus (Kuroichigo)	[illegible]
Berberis brachypoda	[illegible]
Caragana microphylla	[illegible]
Acanthopanax setchuensis (Shisenukogi)	[illegible]
Lonicera hispida	[illegible]
Cerasus polytricha	[illegible]
Sophora davidii	[illegible]
Acer stenolobum	[illegible]
Aconitum sungpanense	[illegible]
Rubus pungens var. *indefensus*	[illegible]
Thalictrum baicalense (Harukaramatsu)	[illegible]
Syringa pubescens	[illegible]
Crataegus sanguinea	[illegible]
Ribes burejense	[illegible]
Picea meyeri	[illegible]
Acer truncatum	[illegible]
Rhamnus utilis	[illegible]
Syringa villosa	[illegible]
Carex rigescens	[illegible]
Spiraea trilobata	[illegible]
Saussurea nivea	[illegible]
Rosa acicularis (Ootakaneibara)	[illegible]
Deutzia parviflora	[illegible]
Lonicera maackii (Hanahyoutanboku)	[illegible]
Pyrus betulaefolia	[illegible]
Daucus carota (Noraninjin)	[illegible]
Syringa pekinensis	[illegible]
Bupleurum chinensis	[illegible]
Saposhnikovia divaricata	[illegible]
Cotoneaster submultiflorus	[illegible]
Spiraea pubescens	[illegible]
Quercus liaotungensis	[illegible]
Smilax stans (Marubasankirai)	[illegible]
Polygonatum sibiricum	[illegible]
Prunus sibirica	[illegible]
Lonicera ferdinandii	[illegible]
Cotoneaster multiflorus	[illegible]
Ostryopsis davidiana	[illegible]
Rosa xanthina	[illegible]
Cotoneaster acutifolius	[illegible]
Tipularia szechuanica	[illegible]
Crataegus kensuensis	[illegible]
Viburnum schensianum	[illegible]
Rosa hugonis	[illegible]
Atractylodes lancea	[illegible]
Abelia biflora	[illegible]
Prunus tomentosa	[illegible]
Cotoneaster zabelii	[illegible]
Rhododendron dauricum	[illegible]
Larix gmelini	[illegible]
Pyrola renifolia (Jinyouichiyakusou)	[illegible]
Salix taraikensis	[illegible]
Cornus alba	[illegible]
Climacium dendroides	[illegible]
Phryma leptostachy	[illegible]
Populus ussuriensis	[illegible]
Viburnum burejaeticum	[illegible]
Carex pilosa	[illegible]
Adenocaulon himalaicum (Nobuki)	[illegible]
Saussurea discolor	[illegible]
Pyrus ussuriensis	[illegible]
Carex pediformis var *pedunculata*	[illegible]
Sanguisorba longifolia	[illegible]
Acer triflorum	[illegible]
Abies holophylla	[illegible]
Acer barbinerve	[illegible]
Polystichum subtripteron	[illegible]
Geranium maximowiczii	[illegible]
Vicia amurensis (Noharakusahuji)	[illegible]
Cirsium pendulum	[illegible]
Geranium vlassowianum	[illegible]
Galium maximowiczii	[illegible]
Artemisia desertorum	[illegible]
Clinopodim chinense var. *grandiflorum*	[illegible]
Adenophora pereskiifolia	[illegible]
Poa ochotensis (Ichigotsunagi)	[illegible]
Kitagawia eryngiifolia	[illegible]
Lonicera maximowiczii	[illegible]
Carex xiphium	[illegible]
Athyrium crenatum	[illegible]
Picea jezoensis (Ezomatsu)	[illegible]
Waldsteinia ternata (Kokinbai)	[illegible]
Circaea alpina (Miyamatanitade)	[illegible]
Acanthopanax senticosus (Ezoukogi)	[illegible]
Euonymus pauciflorus	[illegible]
Tilia mandshurica	[illegible]
Cardamine leucantha (Konronsou)	[illegible]
Philadelphus schrenkii	[illegible]
Deutzia glabrata	[illegible]
Viburnum sargentii (Kanboku)	[illegible]
Polygonatum involucratum (Waniguchisou)	[illegible]
Pinus koraiensis (Chosengoyou)	[illegible]
Ulmus laciniata (Ohyou)	[illegible]
Acer tegmentosum	[illegible]
Carex ussuriensis	[illegible]
Phellodendron amurense (Kihada)	[illegible]
Fraxinus mandshurica	[illegible]
Cacalia hastata	[illegible]
Diarrhena mandshurica	[illegible]
Polygonatum humile (Himeizui)	[illegible]
Sorbaria sorbifolia	[illegible]
Pseudostellaria sylvatica (Kushirowachigaisou)	[illegible]
Rhamnus davurica	[illegible]

Aegopodium alpestre (Ezobouhu)	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	IV	III	V	V	III	IV	2	II	I	II	I	I	r	·	·
Ribes mandshuricum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	III	r	·	IV	III	+	IV	·	I	·	I	III	·	·	II	III
Convallaria keiskei (Suzuran)	·	·	·	·	·	·	·	·	·	·	·	III	r	r	+	·	·	·	·	·	·	·	·	r	·	r	·	·	·	·	·	·	·	·	I	·	·	·	·	·	·	·	·	·	·	·	I	V	II	IV	I	II	IV	III	·	II	V	IV	II	IV	V	I	III
Schisandra chinensis (Chosengomishi)	·	·	·	·	·	·	·	·	·	I	I	III	I	·	r	·	r	·	·	·	·	·	·	r	r	r	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	III	III	IV	V	V	II	IV	3	II	·	III	V	II	II	III	III
Quercus mongolica (Mongorinara)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	V	V	IV	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	V	III	V	III	IV	V	V	4	V	V	V	IV	V	V	III	IV
Tilia amurensis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	III	I	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	·	·	·	·	I	II	IV	V	IV	IV	IV	I	2	III	IV	V	III	III	II	IV	IV
Maackia amurensis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	I	II	I	III	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	I	II	II	II	II	I	·	IV	IV	I	II	III	III	I	II
Aster scaber (Shirayamagiku)	·	·	·	·	·	·	·	·	·	·	·	I	I	I	+	I	II	II	·	·	·	III	II	II	III	II	III	I	·	I	·	·	I	·	·	·	·	·	·	·	·	·	·	I	III	·	·	·	II	+	r	II	IV	II	3	IV	V	IV	+	IV	V	·	+
Carex siderosticta (Taganesou)	·	III	·	·	·	·	+	+	·	·	·	I	+	I	II	I	+	r	·	·	·	III	II	V	III	III	·	·	·	·	II	IV	·	·	·	·	·	·	·	·	·	·	·	·	II	·	II	IV	IV	II	III	III	I	2	IV	I	+	II	III	IV	III	II
Common species in Quercetea mongolicae & *Quercus liaotungensis* forest																																																														
Malus baccata (Shiberiaringo)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	·	·	r	·	·	·	·	·	·	II	II	II	·	II	I	II	II	·	·	II	·	II	II	+	·	·	+	II	III	I	II	·	I	I	+	+	I	r	·	r
Lonicera chrysantha (Nemurobushidama)	·	·	·	·	·	·	·	·	·	·	·	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+	III	III	·	V	·	·	·	·	II	·	·	IV	II	I	III	III	III	I	V	V	I	III	·	+	·	·	III	·	+	+	III
Populus davidiana (Chosenyamanarashi)	·	·	·	·	·	·	·	·	·	·	·	r	r	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	I	·	·	II	I	·	+	II	II	II	·	II	II	II	II	I	+	II	II	I	V	4	·	III	II	·	·	·	·	·
Betula platyphylla	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	·	I	I	·	II	·	·	II	·	IV	IV	V	V	II	II	II	·	+	III	2	·	I	I	I	II	r	I	II
Berberis amurensis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	·	·	II	·	III	·	·	II	I	II	·	V	II	+	r	+	I	·	+	·	+	I	I	·	III	III
Ulmus macrocarpa (Oominire)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	II	·	·	I	·	III	·	I	·	·	+	II	·	II	III	III	IV	II	III	1	II	II	II	·	·	·	·	·
Veratrum nigrum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	·	·	·	I	·	·	I	·	·	·	·	·	III	II	·	I	IV	III	·	·	·	I	+	·	II	·	+	III	III	I	·	·	·	r
Rhamnus parvifolia	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	+	·	·	·	·	I	·	·	III	·	III	·	·	·	·	II	·	r	II	I	I	I	II	·	+	III	III	·	·	·	·	·
Sedum aizoon (Hosobanokirinsou)	·	+	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	III	III	·	·	·	r	·	II	·	·	·	I	II	III	IV	·	·	II	·	+	IV	·	·	II	V	II	·	III	III	·	·
Dioscorea nipponica (Uchiwadokoro)	·	+	·	·	·	·	·	·	·	·	·	·	I	r	I	·	·	·	·	·	·	·	r	+	r	·	II	·	·	II	IV	IV	V	V	IV	II	·	·	IV	V	III	IV	IV	·	V	II	·	·	III	III	III	III	III	1	III	IV	III	I	IV	III	+	I
Euonymus alatus (Nisikigi)	·	·	·	·	·	·	·	·	·	·	·	II	r	r	I	I	I	r	·	·	·	·	r	r	+	+	·	·	·	·	·	·	III	IV	·	V	II	I	I	I	II	·	II	·	+	·	·	r	IV	IV	III	II	IV	·	IV	III	II	·	r	I	·	r
Acer ginnala	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	r	·	·	II	II	2	·	·	·	·	III	·	II	III	IV	IV	V	·	·	·	IV	·	I	·	II	+	I	II	·	V	·	·	·	III	·	I	·	·	·
Corylus heterophylla (Oohashibami)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	I	·	I	·	·	+	·	·	V	·	·	I	·	I	I	·	IV	·	·	·	·	·	·	II	II	IV	III	III	I	1	II	V	IV	r	III	IV	·	·
Corylus mandshurica (Ootsunohashibami)	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	II	II	II	II	·	·	·	·	·	·	·	·	·	·	·	·	II	·	III	·	·	IV	IV	·	II	IV	III	II	III	III	IV	4	II	II	·	II	II	I	IV	IV
Fraxinus rhynchophylla	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	IV	II	III	III	III	I	·	·	II	·	·	·	·	·	·	·	·	·	·	·	V	III	·	·	·	·	·	·	r	r	I	·	·	V	III	·	II	II	III	·	·
Lespedeza bicolor (Ezoyamahagi)	·	·	·	·	·	·	·	·	·	·	·	I	·	·	·	·	·	·	·	·	·	·	II	+	II	·	·	·	·	+	·	·	III	·	·	·	r	+	III	III	V	V	IV	IV	IV	IV	II	I	I	r	I	V	·	4	IV	V	IV	I	V	IV	·	·
Common species with Querco mongolicae– Betuletea davuricae																																																														
Fragaria orientalis	·	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	II	·	·	·	·	·	I	·	II	·	·	IV	·	I	·	·	I	·	r	II	·	·	+	·	IV	+	III	r	·	·
Synurus deltoides	·	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	II	+	·	I	·	·	+	·	·	·	·	I	·	·	·	·	·	·	·	IV	·	III	+	·	I	·	·	·	I	·	·	I	II	II	·	III	II	·	r
Betula davurica (Koonoore)	·	·	·	·	·	·	·	·	·	·	·	I	·	r	+	·	·	·	·	·	·	·	r	r	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	I	IV	II	I	I	·	·	·	III	·	1	I	V	V	I	IV	II	·	r
Trifolium lupinaster (Syakujousou)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	II	·	·	·	·	II	·	·	·	·	+	·	r	+	·	·
Chrysanthemum zawadskii (Iwagiku)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	r	·	·	·	·	·	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I	·	·	·	·	II	·	·	·	·	I	·	·	·	·	·
Galium boreale	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	·	·	·	r	r	·	·	·	·	·	·	·	II	I	·	·
Astragalus membranaceus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	·	·	·	·	·	·
Spiraea media (Ezoshimotsuke)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r
Artemisia tanacetifolia	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Saussurea elongata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Pulsatilla patens	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Carex amgunensis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Scorzonera radiata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Elymus gmelinii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Poa botryoides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Aster alpinus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Adenophora tricuspidata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Anemonastrum crinitum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Others																																																														
Carex lanceolata (Hikagesuge)	+	·	·	III	·	·	·	·	·	·	+	II	I	+	I	II	II	I	·	·	·	III	II	I	III	II	V	V	·	+	·	·	IV	V	IV	V	V	V	V	V	V	V	V	V	III	V	V	IV	IV	IV	IV	IV	IV	2	I	I	V	+	III	II	+	+
Polygonatum odoratum sl. (Amadokoro rui)	·	+	·	IV	·	·	·	·	·	±	+	III	I	r	r	·	·	·	·	·	·	·	+	II	I	II	IV	I	·	III	III	IV	III	V	III	V	III	III	III	IV	V	V	III	V	V	IV	IV	III	II	III	II	III	IV	1	III	II	+	·	I	IV	·	·
Aster ageratoides sl. (Shiroyomena rui)	+	III	·	·	·	·	·	I	·	·	·	·	I	I	II	I	II	I	IV	·	·	·	·	r	r	r	V	IV	·	III	III	V	V	V	IV	IV	·	·	V	V	III	V	III	III	IV	III	·	·	·	+	I	·	·	1	III	·	I	+	II	I	I	I
Sorbus alnifolia (Azukinashi)	·	II	·	I	·	·	II	I	II	III	III	IV	V	III	III	II	r	+	I	I	II	III	II	III	III	III	III	·	·	·	III	III	II	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	II	II	I	III	·	III	I	I	I	I	+	·	·
Acer mono (Itayakaede)	·	·	·	·	·	·	·	·	·	·	·	·	r	+	+	r	·	·	·	·	II	I	III	III	II	III	·	·	·	II	+	III	III	·	V	·	·	·	·	·	·	I	IV	·	·	II	·	V	V	V	V	IV	V	4	III	III	V	V	IV	II	IV	IV
Kalopanax pictus (Harigiri)	+	+	·	·	I	II	II	I	II	IV	V	V	IV	II	II	II	III	+	III	·	·	·	I	II	I	II	II	V	2	·	II	III	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	·	·	III	I	+	·	r
Sorbus commixta (Nanakamado)	·	·	·	·	V	I	+	I	III	IV	IV	I	II	II	II	r	·	r	III	·	·	·	·	II	I	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Carpinus cordata (Sawashiba)	·	IV	·	·	·	·	I	I	·	+	II	III	III	+	II	+	·	·	·	III	·	I	I	II	I	III	·	·	·	·	·	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	·	·	IV	·	·	·	·
Cornus controversa (Mizuki)	II	I	·	·	II	I	I	I	I	·	I	I	III	I	II	I	II	r	III	I	II	I	III	II	I	II	·	·	·	·	I	II	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·
Disporum smilacinum (Chigoyuri)	·	·	·	·	·	I	II	I	II	II	+	I	III	III	III	II	II	II	·	V	IV	II	II	III	III	III	I	I	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	+
Viburnum erosum sl. (Kobanogamazumi rui)	I	IV	I	V	·	+	I	I	·	·	·	·	·	II	+	III	III	IV	III	III	II	·	I	r	I	II	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·

4) Riparian forests: syntaxonomic system of the riparian forests of South Korea (excluding Ulleung-Do Island)

Keiichi Ohno (Graduate School of Environment and Information Sciences, Yokohama National University)
Jong-Suk Song (Department of Biological Science, College of Natural Sciences, Andong National University)

Abstract

The syntaxonomic system for riparian vegetation, including ravine forests in the warm-temperate zone and valley-bottom forests in the cool-temperate zone of South Korea, was surveyed in this study. The ravine forests are classified into three syntaxa: an Acero-Zelkovetum serratae, an *Acer palmatum* var. *coreanum-Zelkova serrata* community, and an *Aconitum loczyanum-Zelkova serrata* community. These syntaxa generally occur in the talus and colluvium of ravines in the warm-temperate zone of southern to central regions of South Korea. They are grouped into the alliance Corno-Zelkovion serratae, which corresponds to the Japanese Zelkovion serratae. The valley-bottom forests are classified into two syntaxa: a *Cimicifuga simplex* var. *typica-Fraxinus mandshurica* var. *japonica* community and a *Clematis urticifolia-Ulmus vavidiana* community. These syntaxa mostly occur in the valley-bottoms of ravines in the cool-temperate zone of northeastern South Korea. They are placed in the alliance Fraxino-Ulmion davidianae, which corresponds to the Japanese Ulmion. These two alliances can be included in the order Fraxino-Ulmetalia, based on common character species. From these results we concluded that the order Fraxino-Ulmetalia, a zonal vegetation type, belongs in the class group composed of the Quercetea mongolicae in South Korea and Fagetea crenatae in Japan.

Introduction

Several types of riparian forest occur on levees and fluvial terraces along rivers and streams in South Korea. Each riparian forest type has a peculiar species composition, habitat and ecological traits. Ravine *Zelkova serrata* forests, as riparian forest, are found on alluvial talus and colluvium in the lower montane belts in the warm-temperate zone, in which most forest vegetation consists of summergreen secondary forests characterized by *Quercus serrata* and *Q. variabilis*. Valley-bottom *Fraxinus mantshurica* forests, as another type of riparian forest, occur on fluvial terraces of upper streams in the montane belt of the cool-temperate zone, in which *Q. mongolica* is the most dominant tree.

As for the relation between vegetation zones and syntaxonomic systems in South Korea, evergreen forests in the warm-temperate zone correspond to the class Camellietea japonicae (Kim 1992), broad-leaved deciduous forests in the cool-temperate zone are equivalent to the class Quercetea mongolicae (Song 1988), and coniferous forests in the boreal zone are parallel to the class Vaccino-Piceetea (Song 1986). Thus, syntaxonomic systems for climatic-climax forest communities corresponding to vegetation zones in South Korea are mostly defined. Syntaxonomic systems for edaphic-climax forest communities, such as ravine *Zelkova* forests and valley-bottom *Fraxinus* forests, however, are not yet established in this country. Therefore, the authors have done this syntaxonomic study on the riparian forest communities in South Korea (except for Ulleung-Do island).

1. Vegetation units of riparian forest communities

In several research programs we have studied the riparian forest communities in South Korea, including ravine *Zelkova* forests and valley-bottom *Fraxinus* forests, phytosociologically. Several vegetation units of these riparian forest communities are describedbelow.

1.1 Acero-Zelkovetum serratae Kim et Yim 1988

Ravine *Zelkova* forests occur on Mt. Naejang of west-central South Korea, located in the warm-temperate southern zone, in which the dominant forest vegetation types are secondary or semi-natural forests mixed with deciduous oak trees (*Quercus serrata* and *Q. variabilis*). These *Zelkova* forests are classified into the association Acero-Zelkovetum serratae (Kim & Yim, 1988). This syntaxon is characterized by such character and differential species as *Celtis sinensis* var. *japonica* and *Galium trachyspermum* (Table 1-A).

1.2 *Acer palmatum* var. *coreanum-Zelkova serrata* community

Similar ravine *Zelkova* forests are found in Seonunsan (Kim & Yim 1986) adjoining Mt. Naejang and also occur in the Sanggyesa area of Jin-Do island, in southernmost South Korea, in the evergreen forest zone (Camellietea region). These *Zelkova* forests are classified into the *Acer palmatem* var. *coreanum-Zelkova serrata* community, which is characterized by such differential species as *Acer palmatem* var. *coreanum,* and *Orixa japonica,* and contains floristic elements (*Liriope muscari, Hedera rhombea, Ophiopogon japonicus*) of the class Camellietea japonicae (Table 1-B).

1.3 *Aconitum loczyanum-Zelkova serrata* community

Another ravine *Zelkova* forest occurs on Mt. Chiri, Mt. Kaya, Mt. Kyeryong, Mt. Chuwang and Mt. Chongnyang. This forest type occurs widely from south to north in the warm-temperate zone in South Korea. It is classified into the *Aconitum loczyanum-Zelkova serrata* community and is characterized by such differential species as *Euonymus alatus* f. *ciliato-dentatus, Aconitum loczyanum, Lespedeza maximowiczii* and *Vicia unijuga* (Table 1-C).

1.4 *Cimicifuga simplex* var. *typica-Fraxinus mandshurica* var. *japonica* community

Valley-bottom *Fraxinus* forests are found on debris flows in upper streams of Mt. Taebaek, located in northeastern South Korea, in the cool-temperate zone, the so-called Quercetea monglicae region. These *Fraxinus* forests are classified as part of the *Cimicifuga simplex* var. *typica-Fraxinus mandshurica* var. *japonica* community.

It is characterized by such differential species as *Deutzia paniculata, Acer tschonoskii, Pseudostellaria davidii, Cimicifuga simplex* var. *typica, Polystichum braunii* and others (Table 1-D).

1.5 *Clematis urticifolia-Ulmus davidiana* community

Wetland *Ulmus* forests occur sporadically on talus and on colluvial soils in the montane belts of Mt. Odae and Mt. Sobaek, located in northeastern South Korea in the northern warm-temperate zone and also in the cool-temperate zone (Quercetea monglicae region). These *Ulmus* forests are classified into the *Clematis urticifolia-Ulmus davidiana* community. It is characterized by such differential species as *Deutzia glabrata, Clematis urticifolia, Galium trifleriforme* var. *nipponicum, Viola variegatea* and *Dryopteris monticola* (Table 1-E).

1.6 Corno-Zelkovion serratae Kim et Yim 1988

The ravine *Zelkova* forest communities in South Korea are classified into three syntaxa: an Acero-Zelkovetum serratae, an *Acer palmatem* var. *coreanum-Zelkova serrata* community, and an *Aconitum loczyanum-Zelkova serrata* community. These syntaxa are grouped into the alliance Corno-Zelkovion serratae based on such character and differential species as *Zelkova serrata, Lindera erythrocarpa, Ligustrum obtusifolium, Viola chaerophylloides* and others (higher unit 1 in Table 1). This alliance corresponds to the Zelkovion serratae (Miyawaki 1977; Ohno 1983) in Japan.

The ravine *Zelkova* forests of South Korea range from the class Camellietea japonicae region in the warm-temperate zone to the class Quercetea mongolicae in the cool-temperate zone. This distribution pattern means that this syntaxon, as an edaphic climax, is an azonal or an extra-zonal vegetation type.

1.7 Fraxino-Ulmion davidianae (all. nov. prov)

The valley-bottom *Fraxinus* forests and the wetland *Ulmus* forests in South Korea are classified into the *Cimicifuga simplex* var. *typica-Fraxinus mandshurica* var. *japonica* community and the *Clematis urticifolia-Ulmus davidiana* community respectively. These syntaxa are grouped into the alliance Fraxino-Ulmion davidianae, determined by such character and differential species as *Ulmus davidiana, Fraxinus mandshurica* var. *japonica*, *Deutzia prunifolia, Diarrhena japonica* and *Cimichifuga davurica* (higher unit 2 in Table 1). This alliance corresponds to the Ulmion (Suzuki 1954) in Japan.

Both the valley-bottom *Fraxinus* forests and the wetland *Ulmus* forests are restricted to region of the class Quercetea mongolicae in the cool-temperate zone. This distribution pattern means that this syntaxon, as an edaphic climax, is also an azonal or an intra-zonal vegetation type.

1.8 Fraxino-Ulmetalia Suz.-Tok. 1966 em. (ord. prov.)

The valley-bottom *Fraxinus* forests and the wetland *Ulmus* forests in Japan are unified into the order Fraxino-Ulmetalia (Suzuki 1966). The alliance Fraxino-Ulmion davidianae of South Korea should probably be combined with this order based on common character species such as *Cardamine leucantha, Staphylea bumalda, Sambucus racemosa* ssp. *kamtschatica, Meehania urticifolia* and others (higher units 3 in Table 1). Thus, the order Fraxino-Ulmetalia ranges over the Fagetea region of Japan and the Quercetea region of South Korea. These distributional and vegetation-geographical features mean that the order is an intra-syntaxon belonging to the Fagus-Quercus class group (Ohno 2008, in press). In this case, this syntaxon should be amended according to the phytosociological nomenclature.

References

Kim J.-U. & Yim Y.-J. 1986. [Classification of forest vegetation of Seonunsan (=Mt. Seonun) area, southwestern Korea.] *Korean J. Ecol.*, 9:209-223 (in Korean).

Kim J.-U. & Yim Y.-J. 1988. Phytosociological classification of plant communities in Mt. Naejang, southwestern Korea. *Korean J. Bot.*, 31:1-31.

Kim J.-W. 1992. Vegetation of northeast Asia on the syntaxonomy and syngeography of the oak and beech forest. Ph.D. Thesis, Wien University. 314 pp.

Miyawaki, A. (ed.) 1977. *Vegetation of Toyama Prefecture*. Toyama Prefecture. 289pp (in Japanese).

Ohno, K. 1983. Pflanzensoziologische Untersuchungen über japanische Flußufer- und Schluchtwälder der montanen Stufe. *J. Sci. Hiroshima Univ.*, 18:235-286.

Ohno, K. (in press). Vegetation-geographic evaluation of the syntaxonomic system of valley-bottom forests occurring in the cool-temperate zone of the Japanese Archipelago. In: *Ecology of Riparian Forests in Japan* (H. Sakio. & T. Tamura, eds.) Springer.

Song J.-S. 1986. The synecological study of boreal coniferous forests in South Korea. Ph.D. Thesis, Kobe University. 77 pp.

Song J.-S. 1988. [Phytosociological study of the mixed coniferous and deciduous broad-leaf forests in South Korea]. *Hikobia*, 10:145-156 (in Japanese).

Suzuki, T. 1954. Forest and bog vegetation within Ozegahara basin. In: Scientific Research of the Ozegahara moor. *Japan Society for the Promotion of Science*, Tokyo, 8:1-12.

Suzuki, T. 1966. [Preliminary system of the Japanese natural communities]. *Forest Env.*, 8:1-12 (in Japanese).

Table 1. Synoptic table of riparian forest communities in South Korea

Serial number	1	2	3	4	5	6	7	8
Community type	A		B		C	D		E
	a1	a2	b1	b2		d1	d2	
Number of relevés	5	5	5	4	7	3	6	3
Average number of species	25	28	35	54	59	63	51	50
Character and differential species of association								
Celtis sinensis Pers. var. japonica (Planch.) Nakai	Ⅲ	Ⅲ	Ⅲ					
Galium trachyspermum A.Gray	Ⅲ	Ⅱ						
Differential species of subass.								
Acer pseudo-sieboldianum Kamarov var. koreanum Nakai		Ⅳ	Ⅴ					
Thalictrum actaefolium Sieb. et Zucc.	Ⅰ	Ⅳ						
Differential species of community								
Acer palmatum thunb. var. coreanum Nakai			Ⅱ	4				
Orixa japonica Thunb.		Ⅱ	Ⅴ	3				
Liriope muscari (Decne) Bailey		Ⅰ	Ⅴ	2				
Hedera rhombea (Miq.) Bean		Ⅰ	Ⅲ	2				
Ophiopogon japonicus (L.f.) Ker-Gawl.			Ⅲ	2				
Carpinus tschonoskii Maxim.	Ⅰ		Ⅴ	1				
Differential species of lower units								
Lilium miquelianum Makino			Ⅴ					
Lycoris radiata (L'Herit.) Herb.		Ⅰ	Ⅳ					
Codonopsis lanceolata (Sieb. et Zucc.) Trautv.			Ⅳ		Ⅰ			
Millettia japonica (Sieb. et Zucc.) A.Gray			Ⅳ					
Prunus sargentii Rehder			Ⅲ					
Nanocnide japonica Blume				4				
Orthoraphium coreanum (Honda) Ohwi				4				
Rhamnella franguloides (Maxim.) Weberb.				3				
Meliosma myriantha Sieb. et Zucc.				3				
Cyrtomium fortunei J.Sm.				2				
Camellia japonica L.				2				
Viburnum wrightii Miq.				2				
Gynostemma pentaphyllum (Thunb.) Makino				2				
Differential species of community								
Euonymus alatus (Thunb.) Sieb. f. ciliato-dentatus (Franch. et Savat.) Hiyama					Ⅴ	1		1
Aconitum loczyanum R.Raymund.					Ⅲ			
Lespedeza maximowiczii C.K.Schn.					Ⅲ			
Vicia unijuga A.Br.					Ⅲ			
Differential species of lower units								
Acanthopanax senticosus (Rupr. et Maxim.) Harms					Ⅱ			
Euonymus sieboldianus Blume					Ⅱ			
Evodia danielii Bennett					Ⅱ			
Streptolirion cordifolium (Griffith) O. Kuntze					Ⅱ			
Circaea cordata Royle					Ⅱ			
Celtis leveillei Nakai					Ⅱ			
Polygonatum inflatum Komar.					Ⅱ			
Differential species of community								
Deutaia paniculata Nakai						3	Ⅴ	
Polystichum braunii (Spenn.) Fee						3	Ⅴ	
Betula ermanii Cham.						3	Ⅳ	
Pseudostellaria davidii (Fanchet) Pax						2	Ⅴ	
Acer tschonoskii Max. var. rubripes Komarov						2	Ⅴ	
Aconitum jaluense Kom.					Ⅰ	2	Ⅳ	
Athyrium brevifrons Nakai ex Kitagawa						1	Ⅴ	
Chrysosplenium flagelliferum Fr.Schm.				1		1	Ⅴ	
Cimicifuga simplex Wormsk.var. typica Nakai						3	Ⅳ	
Geum aleppicum Jacq.					Ⅰ	3	Ⅲ	
Scutellaria japonica Morren et decaisne						1	Ⅴ	
Galium paradoxum Maxim.						1	Ⅴ	
Phellodendron amurense Rupr.						1	Ⅳ	
Angelica gigas Nakai						2	Ⅲ	
Abies nephrolepis Max.						1	Ⅲ	
Cacalia hastata L. ssp. orientalis Kitam.						1	Ⅲ	
Salix bakko Kimura						1	Ⅲ	
Aconitum gigas Lev. et Van. var. hondoense (Nakai) Tamura						2	Ⅱ	
Differential species of lower units								
Saussurea grandifolioides Nakai						3		
Lychnis cognata Maximowicz						3		
Aster scaber Thunb.		Ⅰ	Ⅱ			2		
Geranium eriostemon Fischer var. megalanthum Nakai						2	Ⅰ	
Chrysosplenium trachyspermum Maximowicz						2	Ⅰ	
Smilacina japonica A. Gray var. mandshurica Maximowicz					Ⅰ	2		
Heracleum nipponicum Kitagawa						2		
Galium kamtschaticum Steller var. acutifolium Hara						2		

Table 1. (continued)

Serial number	1	2	3	4	5	6	7	8
Community type	A		B		C	D		E
	a1	a2	b1	b2		d1	d2	
Number of relevés	5	5	5	4	7	3	6	3
Average number of species	25	28	35	54	59	63	51	50
Acer ukurunduense Trautv. et C.A.Mey.							IV	
Dryopteris austriaca (Jacq.) Woynar ex Schiz et Thell.							IV	
Ulmus laciniata (Trautv.) Mayr							IV	
Chrysosplenium ramosum Maxim.							V	
Circaea alpina L.							IV	
Pinus koraiensis Sieb. et Zucc.							III	
Oxalis acetosella L.							III	
Sorbus commixta Hedl.							III	
Syringa formosissima Nakai							III	1
Differential species of community								
Deutzia glabrata Komarov					I			3
Clematis urticifolia Nakai ex Kitagawa				1				3
Galium trifloriforme Komarov var. nipponicum (Makino) Nakai								2
Dryopteris monticola (Makino) C.Chr.				1		1		2
Viola variegata Fisch.					I			2
Character and differential species of higher unit-1								
Zelkova serrata (Thunb.) Makino	IV	V	V	4	V			
Lindera erythrocarpa Makino	V	III	III	3	III			
Oplismenus undulatifolius (Ard.) Roemer et Schult.	IV	V	III	1	V			
Ligustrum obtusifolium Sieb. et Zucc.		II	V	4	III			
Akebia quinata (Thunb.) Decne.		IV	IV	2	III			
Viola chaerophylloides (Regel) W.Beck.	I		III	1	III			
Antenoron filiforme (Thunb.) Roberty et Vautier	II	II	III	1	III			
Rabdosia inflexa (Thunb.) Hara	III	I	I	1	III			
Disporum viridescens (Maxim.) Nakai	I	I	II		III			
Celtis jessoensis Koidz.				3	IV			
Dryopteris varia (L.) O.Kuntze var. setosa (Thunb.) Ohwi				2	III			
Picrasma quassioides (D.Don) Benn.				1	III			
Diospyros lotus L.				1	III			
Hovenia dulcis Thunb.				2	II			
Dryopteris lacera (Thunb.) O.Kuntze				3	I			
Character and differential species of higher unit-2								
Diarrhena japonica Franch. et Savat.					IV	3	V	3
Deutzia prunifolia Rehder					III	3	V	2
Fraxinus mandshurica Rupr. var. japonica Maxim.	III				I	3	V	3
Cimicifuga davurica Maximowicz					I	3	V	3
Ulmus davidiana Planchon					III	2		3
Lamium barbatum (Sieb. et Zucc.) Franch. et Savat.					III	2	III	
Character and differential species of higher unit-3								
Philadelphus schrenckii Rupr.				3	IV	3	III	3
Cardamine leucantha (Tausch) O.E.Schulz				3	IV	2	III	1
Sambucus racemosa L. ssp. kamtschatica (E.Wolf) Hulten				3	III	1	IV	2
Meehania urticifolia (Miq.) Makino				3		3	II	1
Staphylea bumalda (Thunb.) DC.	III	III	IV	3	V		I	3
Polystichum tripteron (Kunze) Pr.	IV	II		2	II		V	3
Alangium platanifolium (Sieb. et Zucc.) Harms var. trilobum (Miq.) Ohwi	V	III	II	3	III			2
Urtica angustifolia Fischer				1		1	V	1
Ribes mandshuricum (Max.) Komarov				1		1	V	1
Urtica thunbergiana Sieb. et Zucc.					III	2		1
Laportea bulbifera (Sieb. et Zucc.) Wedd.				2		2	I	
Character and differential species of higher unit-4								
Lindera obtusiloba Blume	IV	V	II		IV	1	I	2
Corylus sieboldiana Blume			II	1	III			2
Styrax japonicus Sieb. et Zucc.	I	I	IV	2	III			
Sapium japonicum (Sieb. et Zucc.) Pax	I	II	I	1	III			
Viburnum dilatatum Thunb.	III	I	III	1	II			
Disporum smilacinum A.Gray	I	I	I		II			
Quercus serrata Thunb.	I				II			
Castanea crenata Sieb. et Zucc.			II		II			
Quercus aliena Blume	I	II	IV	1				
Carpinus laxiflora (Sieb. et Zucc.) Bl.	II			1				
Fraxinus sieboldiana Bl.			I		I			
Quercus variabilis Blume	I		I					

Table 1. (continued)

Serial number	1	2	3	4	5	6	7	8
Community type	A		B		C	D		E
	a1	a2	b1	b2		d1	d2	
Number of relevés	5	5	5	4	7	3	6	3
Average number of species	25	28	35	54	59	63	51	50
Callicarpa japonica Thunb.				4	III			
Phryma leptostachya L. ssp. asiatica Hara				3	III			
Securinega suffruticosa (Pall.) Rehd. var. japonica (Muell.-Arg.) Hurusawa				1	III			
Cornus macrophylla Wall.				1	III			
Pourthiaea villosa (Thunb.) Decne. var. laevis (Thunb.) Stapf				2	I			
Viburnum erosum Thunb. var. punctatum Franch. et Savat.				1	I			
Benthamidia japonica Hara				1	I			
Character and differential species of Quercetea mongolicae								
Fraxinus rhynchophylla Hance	I	I	I	1	V	3	IV	2
Pseudostellaria palibiniana (Takeda) Ohwi				1	V	3		3
Acer pseudo-seiboldianum Kamarov.		I		1	III	3	II	3
Euonymus oxyphyllus Miq.				1	II	1	V	2
Polygonatum involucratum (Franch. et Savat.) Maxim.				1	II	2	V	
Vitis amurensis Rupr.					III	2	II	2
Athyrium vidalii (Franch. et Savat.) Nakai				1	III	2	III	
Viola selkirkii Pursh				2			V	1
Weigela florida (Bunge) A.DC.				1	III	2	II	
Aster ageratoides Turcz. ssp. ovatus (Franch. et Savat.) Kitam.				1	III	1		2
Smilacina japonica A.Gray				3	III			2
Polygonatum odoratum (Mill.) Druce var. pluriflorum (Miq.) Ohwi	I			1	III	1		
Viola albida Palibin					II	1		2
Asiasarum sieboldii Miq.			I		II	1	I	
Dryopteris crassirhizoma Nakai	I					3	V	2
Rabdosia shikokiana (Makino) Hara var. lecantha (Murai) Hara f. kameba (Okuyama ex Ohwi)		II				3	V	3
Astilbe chinensis Maximowicz ex Franchet et Savatier. var. coreana Nakai					I	3	V	1
Prunus padus L.						1	V	3
Magnolia sieboldii K.Koch ssp. japonica Ueda					I	1	V	2
Acer mandshuricum Max.						1	V	1
Schisandra chinensis (Turcz.) Baill.						3	III	3
Actinidia kolomikta (Maxim. et Rupr.) Maxim.						2	III	1
Tilia amurensis Rupr						1	III	2
Quercus mongolica Fischer						1	III	1
Corylus mandshurica Maxim.						3	II	1
Character and differential species of Camellietea japonicae								
Liriope spicata (Thunb.) Lour.		II		2	I			
Torreya nucifera (L.) Sieb. et Zucc.		V		3				
Cephalotaxus harringtonia (Knight) K.Koch				1	II			
Trachelospermum asiaticum (Sieb. et Zucc.) Nakai f. intermedium (Nakai) Murata	I	I	IV	1				
Daphniphyllum macropodum Miq.	II			1				
Companions								
Acer mono Maxim.	IV	IV	IV	2	V	3	V	2
Arisaema amurense Maximowicz var. typicum Nakai	II	I	III	2	IV	2	IV	2
Cornus controversa Hemsley	IV	II	IV	3	III	2	V	1
Viola acuminata Ledeb.	III	II	I	1	I	1	III	
Carpinus cordata Blume	I		I	1	II	1	I	1
Actinidia arguta (Sieb. et Zucc.) Planch.	II			2	III	1	II	2
Stephanandra incisa (Thunb.) Zabel		I	III	1	III	3		1
Impatiens textori Miq.	I			1	II	3	I	2
Sasamorpha borealis (Hack.) Nakai	III	III	II	3	II			1
Hydrangea macrophylla (Thunb.) Seringe var. acuminata (Sieb. et Zucc.) Makino	III	II		1	I		II	2
Clematis apiifolia DC.	I	I		1	III		I	1
Carex siderosticta Hance			I		II	1	I	1
Desmodium podocarpium DC. ssp. oxyphyllum (DC.) Ohashi	I	I	I	2	I			
Morus australis Poir.		I		2	IV			2
Rubia argyi (Lev. et Van.) Hara		I		1	IV			2
Other species are not listed								

References and locations: Serial no. 1, 2: Kim & Yim (1988), Mt. Naejang; 3: Kim & Yim (1986), Seonunsan; 4: Original data (2001, 2006), Seonunsan, Jindo, Mt Naejang; 5: Original data (1997, 2001), Mt. Kyeryong, Mt. Chiri, Mt. Kaya, Mt. Chongnyang, Mt. Chuwang; 6, 7: Original data (2004), Mt. Taebaek; 8: Original data (1997, 1998), Mt. Odae, Mt. Sobaek.

5) Evergreen Broad-Leaved Forest

Song Yongchang, Da Liangjun (*Department of Environmental Sciences, East China Normal University*)

Elgene O. Box (*Department of Geography, University of Georgia, Athens, Georgia, USA*)

Kazue Fujiwara (*Graduate School of Environment and Information Scienses, Yokohama National University*)

The description evergreen broad-leaved forest could describe the potential natural vegetation of the humid tropical, subtropical and warm-temperate zones of the world, including tropical rainforests, subtropical to warm-temperate "laurel" forests, and tropical montane forests. In our mainly extra-tropical study, though, we are generally dealing with those subtropical and warm-temperate analogs of the tropical rainforest that constitute the potential natural vegetation of large parts of humid East Asia. These extra-tropical evergreen broad-leaved forests (EBLF), also called "Laurel forests", are composed of trees bearing simple, intermediate-sized, somewhat glossy, dark green (shade-tolerant) laurophylls, i.e. thin-coriaceous but mesomorphic evergreen leaves such as are especially characteristic of the laurel family (Lauraceae).

The main canopy tree genera of laurel forest are *Persea* (=*Machilus*), *Cinnamomum*, *Beilschmiedia*, etc. (Lauraceae); *Castanopsis*, evergreen *Quercus* (=*Cyclobalanopsis*), and *Lithocarpus* (Fagaceae); *Schima* (Theaceae), *Ilex* (Aquifoliaceae), *Michelia* (Magnoliaceae), and others, all with very similar laurophyll physiognomy (cf. Box et al. 1998). Understorey trees and arborescents are largely from the same families. Lauraceae tend to be especially important in more coastal areas, while evergreen Fagaceae tend to become more important inland, especially in southwestern China. Forests dominated by laurophyll trees are rather dark and somber, with low light levels below the canopy, and are evergreen from top to bottom. East Asia contains the world's largest area of such forests, due to its abundant rainfall and winters without severely low temperatures, at least in coastal areas or on islands.

In East Asia, laurel forests occur south of about 35°N latitude: in southeastern China, in drier southwestern China (Sichuan and Yunnan, with different but largely vicariant species), on Taiwan, in southern Japan (but extending to 38°N along both seacoasts), and across southernmost Korea (see Fujiwara 1981-86, Hara & Yonebayashi 1997, Kira 1991; Song 1988, 1995; Wang 1961, Wu 1980). In Southeast Asia, laurel forests also ascend into the mountains to form belts of tropical montane forest co-dominated by Lauraceae and evergreen Fagaceae, plus subtropical Theaceae, Myrsinaceae, Symplocaceae, and Rubiaceae, but also temperate taxa such as Ericaceae and *Ilex* (see Whitmore 1984; cf. Box et al. 1991, Ohsawa 1995). Satellite data have suggested that some relatively large areas of montane rainforest and laurel forest may remain. From the lowland forest to this montane forest, leaf size typically changes from normal mesophyll to a mix of smaller notophyll and microphyll (see Ohsawa 1991, 1995a). Above this there may be a low, dense, distinctly microphyll cloud forest of laurophyll treelets covered by mosses and other epiphytes (cf. Hamilton et al. 1995).

In humid East Asia, the largest species turnover between the polar region and the tropics occurs within the bioclimatic zone of evergreen broad-leaved forests -- without major change in the forest physiognomy. This occurs in the Okinawa Islands of Japan and in southeastern China, as temperate species abruptly disappear, including many laurophyll tree species, and are replaced by an essentially tropical flora which includes many new tree genera with essentially the same evergreen broad-leaved structure.

The mountains of warm-temperate to subtropical East Asia represent the only large mountainous area in those zones in either hemisphere (though smaller areas do occur in Mexico, southern Brazil, eastern Australia, and northern New Zealand). The various mountain systems of humid East Asia, including the eastern Himalaya, thus represent areas of unusual diversity and endemism, especially among what appear to be relict conifers. In most of the area, the lowland biome is evergreen broad-leaved forest, which may extend well into the montane belt in most places, with well developed *Rhododendron* belts and a more warm-temperate character. Extensive evergreen oak forests, involving *Quercus semicarpifolia* and many other species, still occur on the southern slopes of the Himalaya and may represent a somewhat unique warm-temperate forest biome (Zobel & Singh 1997).

In the transition region of eastern China (summergreen to evergreen laurel forest), two quite accessible 'sacred' mountains have well developed zonations which are well described: Huang-Shan in southeastern Anhui province and Tianmu-Shan in northern Zhejiang province (see Song et al. 1994: pp. 174-198). The mountains of Taiwan are especially steep, and the montane laurel forests are consequently relatively well preserved (see Hsieh et al. 1997, Box et al. 1998).

The largest regions of evergreen broad-leaved forest are in China and Japan. For Japan, the evergreen broad-leaved forests were already summarized phytosociologically, in great detail, in the 1980s, by Fujiwara (1981-86) and in the encyclopedic "Vegetation of Japan" (Miyawaki, ed., 1980-89). Given its much larger land area, vegetation summaries in China are usually more general. In the Chinese tradition, forests (and some other vegetation types as well) are usually classified by dominance types, most commonly involving two co-dominant species (see, for example, Wu 1980, 1995). Since these areas were already well studied, our fieldwork focused more on vast, less known areas such as Siberia and western China. Nevertheless, Song and Da were able to combine their knowledge of the literature and their many years of field experience to summarize the evergreen broad-leaved forests of East Asia into a scheme of community groups and dominance types that span the whole region (see table below).

Despite our different traditions and perspectives, we (four co-authors) agree in recognizing three basic types of (extra-tropical) Evergreen Broad-Leaved Forest in East Asia, reflecting differences in climate, ecophysiognomy, and floristic composition:

1) the typical Laurel Forest of the warm-temperate to subtropical zones, with mainly summer rain but cooler winters and thus no regular dry season;

2) subtropical Seasonal Evergreen Forest, representing the transition from the perhumid warm-temperate zone to the tropical zone with dry winter; and

3) subtropical ombrophilous forest, or Subtropical Rainforest, representing the transition from perhumid warm-temperate to perhumid tropical, with no dry period.

In the global climate system of Heinrich Walter (as expanded by Box 2005), these three types would represent, respectively, climatic zones Ve (warm-temperate/humid-subtropical), Ve-II (transition to tropical summer-rain), and Ve-I (transition to perhumid tropical).

The warm-temperate/subtropical laurel forest has mesophyll but also smaller, somewhat more coriaceous (but still thin) leaves, as befit its cooler winter; it also has few lianas or epiphytes. The subtropical seasonal forest has more species, mostly subtropical and tropical, and occurs in more southerly parts of China, as well as southernmost Japan (i.e. Okinawa) and Taiwan. The subtropical rainforest occurs in the wettest habitats, often in valleys, and shows a much more complex structure reminiscent of tropical rainforest, with buttressing on trees, abundant lianas and epiphytes, and large-leaved understorey herbs.

Typical Laurel Forest

The basic characteristics of the typical summer-rain laurel forest, especially in China, were summarized by Song (1994, 1995). It occurs in central and southern Japan, along the south coast of Korea, in the eastern and western parts of southern China, and in the mountains of Taiwan. Based on habitat and floristic components, typical laurel forest can be divided into four regional subtypes.

1) Southeastern China

The dominant species composing the tree layer belong to the genera *Castanopsis, Cyclobalanopsis, Lithocarpus, Machilus, Cinnamomn, Schima,* and *Altingia*. Some warmth and humidity-loving conifers and deciduous trees also occur within these communities, along with a herbaceous layer dominated by Pteridophytes, including tree ferns. The flora is composed of Sino-Japanese elements. Diagnostic species are *Cyclobalanopsis glauca*, *Camellia fraterna, C. cuspidata*, and *C. oleosa*. It can be called

Camellio-Cyclobalanosietea glaucae and can be divided into three groups (Song, 2004), with dominance types as shown in the table below:

i). a *Lithocarpus-Cyclobalanopsis* group, with a wide ecological amplitude and greater cold tolerance, mainly occurring toward the north. Diagnostic for this group are cold and drought-tolerant species of *Lithocarpus* and *Cyclobalanopsis*, such as *Lithocarpus glaber, L. harlandii, L. hancei; Cyclobalanopsis glauca, C. myrsinaefolia, C. sessilifolia, C. gracilis,* and *C. stewardiana.*

ii). a *Schima-Castanopsis* group, the representative type of eastern China, occurring widely in what in Chinese terminology is called the mid-subtropical region. *Schima superba, S. argenta* and species of *Castanopsis* are diagnostic and dominant species.

iii). a *Cinnamomum-Machilus* group, a hydrophilous type of eastern China often seen in moist valleys. The main component species are *Cinnamomum, Machilus, Phoebe* and *Michelia.*

2) Southwestern China

Evergreen broad-leaved forests in southwestern China are found mainly on the northern and central Yunnan Plateau, in Guizhou to the east, and in the mountainous area of southwestern Sichuan. These forests result from the impact of the southwest monsoon from the Indian Ocean, which from summer until autumn brings many rainy days, with heavy precipitation and warm, moist weather. From winter through springtime the weather is warm and dry, because of the monsoonal dry air mass and low precipitation over the continent. The annual temperature variation is relatively small. Canopy trees bear somewhat rigid, relatively small leaves, with hairy dorsal surfaces, slightly crooked trunks, and coarse, thick bark (Song 1988a). This is a drought-adapted, semi-moist evergreen forest, occurring mostly at altitudes of 1600-2500m. The upper tree layer is dominated by species of *Castanopsis*, *Cyclobalanopsis* and *Lithocarpus*; species such as *Cyclobalanopsis glaucoides, Cyclobalanopsis delavayii, Castanopsis orthacansa, Castanopsis delavayii,* and *Lithocarpus dealbatus* are both dominant species and diagnostic species. These forests sometimes have admixtures of a few deciduous trees, such as *Prunus conradinae* and *Celtis yunnanensis*, and some conifers, such as *Pinus yunnanensis*, *Keteleeria evelyniana,* and *Cypressus duclouxiana*. There are also many unique, endemic species. The flora is primarily composed of Chinese-Himalayan elements. This type can be called *Camellio-Cyclobalanopsetea glaucoidis*, and divided into two sub-groups.

i) a *Castanopsis-Cyclobalanopsis* group, the typical semi-moist type, widely distributed in western China and the zonal vegetation type of the central and northern Yunnan Plateau. Xeromophy is obvious in this type. Diagnostic and dominant species are *Cyclobalanopsis glaucoides, Cy. delavayi, Castanopsis orthacantha,* and *Ca. delavayi.*

ii) a *Schima-Lithocarpus* group, the montane forest of the Yunnan Plateau, in the cloud belt at 2000~2900m. The habitat is warm and moist. Dominant and diagnostic are species of *Lithocarpus* and *Manglietia*, plus *Schima noronhae* and species of the bamboo genus *Chimonobambusa*.

3) Japan and Korea

The typical laurel forests of Japan occur mainly in Kyushu, Shikoku, and from Chugoku to central Honshu, extending to near 37°N latitude in coastal areas (Satoo 1983); some authors argue for a limit further north (e.g. Fujiwara 1981). The upper distributional limit is at about 850m on Kyushu, 750m on Shikoku, and 600m on Honshu (Satoo 1983). The climate is a typical monsoon climate, but compared with eastern China, the winter is a little less cold and summer a little less hot. Precipitation is heavier, and humidity is usually high.

The laurel forest in Japan is very similar to its counterpart in eastern China. The canopy is also constituted mainly by *Castanopsis, Cyclobanopsis* and *Machilus*, with *Castanopsis cuspidata*, *Ca. sieboldii*, *Cyclobalanopsis glauca, Cy. myrsinaefolia* and *Machilus thunbergii* as main species. Understorey species are from families such as Theaceae, Cornaceae, and Araliaceae, for example *Camellia japonica, Aucuba japonica, Fatsia japonica, Dendropanax trifidus*, *Ilex integra, Neolitsea serica,* etc. Herb layers are composed largely of Liliaceae, Myrsinaceae and Pteridophytes. The main vines are *Trachelospermum asiaticum* var. *intermedium*, *Hedera rhombea*, and *Kadzura japonica*, but these are usually not large lianas. *Camellia japonica* is designated as the character species, and the class was named *Camellietea japonicae* (Miyawaki and Ohba 1963).

Evergreen broad-leaved forests in Korea are restricted to the south coastal area, where Kira's coldness index is -7° to -10°C (Yim 1977). The floristic composition in Korea is essentially the same as in Japan.

Laurel forests of Japan and Korea were classified into three groups based on the dominant species and spatial distribution (Numata et al. 1972; Miyawaki 1990); phytosociologically they have been classified into one class, 3 orders, 8 formations and 56 associations (Miyawaki 1981, Fujiwara 1981). In order to compare the evergreen broad-leaved forests throughout East Asia, these two systems are synthesized. The evergreen broad-leaved forests of Japan and Korea are divided into two groups, based on eco-physiognomic features and dominant species.

i) a *Lithocarpus-Cyclobalanopsis* group, or "evergreen oak forest" (Numata et al. 1972), dominated by species of *Cyclobalanopsis* and in some cases also by species of *Lithocarpus*. This type has a broad ecological amplitude, is more cold-tolerant, and occurs more in the interior and in mountain regions.

ii) a *Machilus thunbergii-Castanopsis* group, i.e. the so-called *Machilus thunbergii* and *Castanopsis sieboldii* forest (Numata et al. 1972). The dominant species of the tree layer are *Castanopsis sieboldii* and, *C. cuspidata*, accompanied by *Machilus thunbergii*, which sometimes can dominate. This group occurs mainly on terraces and on gentle mountain slopes near the coast, where the habitat is moist and soil is generally deeper. This group can also be compared with the *Myrsino-Castanopsietalia sieboldii*.

4) Taiwan

Evergreen laurel forests once covered the entire island but now occur only in the mountains, at elevations from 800m to 2300m. The upper tree layer is mainly composed of *Cyclobalanopsis, Castanopsis*, and *Machilus* species, such as *Cyclobalanopsis longinux, Cy. morii, Cy. stenophylloides, Castanopsis carlesi, Lithocarpus kawakamii*, and *Machilus thunbergii*. The herbaceous layer is largely composed of ferns. Some thermophilous conifers and deciduous broad-leaved trees may also be found. *Cyclobalanopsis longinux, Cy. morii, Cy. stenophylloides, Trochodendron aralioides , Neolitsea acuminatissima, Symplocos arisanensis* can be recognized as diagnostic species. This type can be called *Castanopsio-Cyclobalanopsetea longinuxi* (Song et al. 2003). It is the montane evergreen forest of Taiwan, occurring on the warm, moist mountains throughout the island (Song et al. 2003a, 2003b, 2004).

Subtropical Seasonal Evergreen BL Forest

This forest type was named "subtropical evergreen seasonal forest" by Ellenberg and Mueller-Dombois (1967). In China, though, it is usually referred to as part of the "monsoon evergreen broad-leaved forest" (Wu 1980). It forms the transition from 'tropical seasonal rain forests' (formally ambiguous in Chinese but apparently meaning seasonal-rain forest, not seasonal rainforest), or semi-deciduous monsoon forest, to evergreen broad-leaved forest; thus it is also known as semi-moist transitional EBLF (Song 1994). The species of the upper storeys are mostly thermophilous species of Fagaceae and Lauraceae, plus many Myrtaceae, Meliaceae, and Moraceae, even a few deciduous species of the 'tropical seasonal rain forest' such as *Albizia, Englhardtia,* and *Bauhinia*. The lower storeys have diverse tropical elements such as species of Rubiaceae, Myrsinaceae, Palmaceae, Leguminoceae, Euphobiaceae, and Rutaceae. Lianas and epiphytic plants, however, are still not as abundant as in the true rainforest, and buttresses and cauliflory are scarcely seen.

Subtropical seasonal EBLFs mainly occur in the southern part of China, on Taiwan, and in southern Japan. Based on the floristic components the seasonal EBLFs can be divided into four subtypes.

1) Southeastern China

Subtropical seasonal EBLFs of southeastern China are dominated by thermophilous species of *Castanopsis, Cryptocarya*, such as *Castanopsis hystrix, Ca. chinensis, Ca. tonkinensis, Ca. uraiana;* and *Cryptocarya chinensis, Cr. concinna;* as well as by species of *Beischmiedia*, *Machilus*, and *Syzygium*. Some trees of Moraceae and Elaeocarpaceae are also important company in the upper layers. The lower-tree and shrub layers are complex, with a great many tropical elements, but lianas and epiphytes are not as abundant as in rainforest. The diagnostic species are *Cryptocarya* and warmth-loving *Castanopsis*. This type can be called *Cryptocaryo-Castanopsietea,* and is divided into two groups (Song 2004).

i) a Cryptocarya-Castanopsis group, which is the warmth-loving EBLF of eastern China, occurring on hills and lower mountains of southern Guangdong, Guangxi, and Fujian. The dominant and diagnostic species are *Cryptocarya chinensis, Cr. concinna, Castanopsis hystrix, Ca. uraiana,* and *Ca. tonkinensis*.

ii) a *Machilus-Beilschmiedia* group, also warmth-loving but also more moisture-demanding, occurring in low mountains at elevations of 400-800m in Guangxi. The diagnostic species are species of *Beischmiedia* and *Machilus*.

2) Southwestern China

This kind of forest is a zonal vegetation of the subtropical Yunnan plateau, occurring at 1100-1500m. Dominant species are thermophilous C*astanopsis* species, such as *Castanopsis hystrix* and *Castanopsis indica*, plus *Schima villosa*, *Schima wallichii*, *Machilus kurzii*, etc. Deciduous species include *Engelhardtia colebrookiana, Allizia chinensis, Kydia calycena* etc., and there are also some conifers, like *Pimus keaiya* var. *langbianenais, Podocazpus imbricatus*, and *P. neriifolia*. The flora is mainly composed of Indo-Malaysian elements, with many species from the tropical rainforests and monsoon forests. The diagnostic species are warmth-loving species of *Machilus* and *Castanopsis*. This type can be called *Machilo kurzii-Castanopsietea* and has two sub-types:

i) a *Lithocarpus-Castanopsis* group, with a very complex species composition. Dominant and diagnostic species are warmth-loving species of *Lithocarpus* and *Castanopsis*, plus *Schima wallichi* and *S. villosa.*

ii) a *Machilus kurzii-Castanopsis* group, occurring mainly on limstone. Dominant and diagnostic species are *Machilus kurzii, Castanopsis hystrix* and *Schefflera diversifolia*.

3) Taiwan

Seasonal EBLF is the zonal vegetation type of the subtropical part (lowlands) of Taiwan. The canopy is mainly composed of thermophilous species of Fagaceae and Lauraceae, such as *Castanopsis carlesii* var. *sessile*, *Cryptocarya chinensi, Machilus japonica* var. *kusanoi*, *Phoebe formosana*, and *Machilus zuihoensis*. Some species of Elaeocarpaceae, Magnoliaceae, Proteaceae, and Ebenaceae are observed too, such as *Sloanea formosana, Michelia compress, Helicia formosan*, and *Diospyros morrisiana*. Frequently seen species in the shrub layer are *Schefflera octophylla, Tricalycia dubia, Pysochotria cochchinensis, Myrsine seguinii, Blastus choeinchinensis*, etc. Large woody lianas are found very often, mostly *Bauhinica chamionii, Mussaeda parviflora, Stauntonia hexaphylla, Hiptage bengalensis, Pileastagia viburnoides, Mucuna macrocarpa*, and *Fissistigma oldhamii* (Song et al. 2003; Song 2004). This type of forest, named *Machilus-Castanopsis* forest by Su (1984), can also be called *Machilo zuihoeno–Castanopsietea*. This type occurs widely on hills and mountains below 800 m. Diagnostic species are *Pithecellobium lucidum, Diospyros morrisiana, Schefflera octophylla, Ardisia quinquegona,* etc. (Song et al. 2003, Song 2004).

4) Southernmost Japan

The seasonal EBLF of Japan mainly occurs on the Ryukyu Islands, between 24° and 26° N latitude. Because the islands are small and composed mainly of limestone and coral reefs, the soil is very thin; additionally, there is heavy impact by human activities, so the seasonal EBLF does not develop well. The floristic composition in general is quite similar to that of the seasonal EBLF on Taiwan and in southeastern China. The main genera are *Beilschmiedia, Schefflera, Ficus, Macaranga, Tarenna, Lasianthus, Pithecellobium, Bredilia, Mallotus, Murraya, Diospyros Psychotria, Bischoffia, Michelia, Myrsine, Turpinia, Lagerstroemia, Cyathea, Psychotria,* and *Livistona* (Miyawaki & Okuda, 1990). This type was named *Diospyro-Mallotetalia philippensis* by Fujiwara (1981).

Subtropical Ombrophilous Forest

Subtropical ombrophilous evergreen broad-leaved forest, also called "subtropical rainforest", forms the transition between tropical rainforest and extra-tropical evergreen broad-leaved forest, occurring mainly in quite moist valleys. The main difference between this type and the previous two is that the structure here is much more complex, usually with plank-buttressing, thick lianas, epiphytic ferns and phanerogams. The physiognomy is more typical of tropical rainforest, with many large-leaved hydrophilous species that have only weak development of mechanisms for protection against transpirational losses.

Subtropical rainforest occurs mainly on Taiwan and in the southernmost parts of southeastern China, including Hong Kong. The herbaceous layer is studded with big-leaved plants and tropical ferns. There are abundant lianas and epiphytes, some quite large. Buttressing, cauliflory, and stranglers are quite remarkable. Based on floristics, the ombrophilous forest can be divided into two subtypes.

1) Southeastern China

Subtropical rainforests occur in southernmost Fujian, Guangdong, Guangxi, and in Hong Kong. Frequent canopy trees are species of *Ficus, Machilus, Syzygium* and *Castanopsis*. The tropical species of *Ficus* and *Machilus* are recognized as diagnostic species, so this type can be called *Fico-Machiletea*; it has two sub-groups.

i) a *Syzygium-Castanopsis* group that occurs in southern Fujian; dominant and diagnostic species are *Castanopsis uraiana, C. hystrix* and *Syzygium hancei.*

ii) a *Ficus-Cleistocalyx* group that occurs in southern Guangdong, Guangxi, and Hong Kong. The dominant and diagnostic species here are *Ficus* spp. *Syzygium* spp. *Cleistocalyx operculatus, Endospermum chinense, Pithecellobium clyperia, Sterculia lanceolata*, *Aqularia sinensis* etc.

2) Taiwan

Subtropical ombrophilous forest occurs in Taiwan at lower elevations where precipitation (3500-4000mm) and temperature (annual mean 18-20°C) are both high, especially in moist ravine habitats. These forests are rather tall, with complicated stratification, and the canopy looks uneven. Frequent taxa in the tree layers are *Ficus*, *Dysoxylum buskusense, Lagerstroemia subcostata, Bischofia javanica, Machilus japonica* var. *kusanoi,* and *Turpinia ternata.* The shrub layer is more complicated, perhaps due to frequent disturbance by typhoons. Main taxa are *Dendrocnida meyeniana, Lasianthus chinensis, Leea guineensis*, and *Cyathea* species. Large, woody lianas and angiosperm epiphytes grow luxuriously; among them the main species are: *Derris laxiflora, Hiptage benghalensis, Pothos chinensis, Erycibe henryi, Mucuna macrocarpa, Ficus sarmentosa* var. *nipponica,* and *Asplenium nidus*. Buttressing and cauliflory are observed. Tree ferns and other large herbaceous plants are numerous (Song et al. 2003). This type of forest might be similar to the so-called *Ficus-Machilus* forest suggested by Su (1984). The diagnostic species are species of *Ficus, Machilus,* and *Cyathea, Alocasia.* It can also be called *Fico-Machiletea*. In the only recognized grouping, the tree layer is mainly composed of *Ficus* species, plus warmth-loving species of *Castanopsis* and *Machilus*. Diagnostic species are *Arenga engleri, Cyathea podophylla, Calamus formosana, Daemonrops mararitae* and *Alocasia macrorrhiza.*

Perspective

EBLF in East Asia is a unique vegetation type resulting from the monsoon climate; it is not only distinctly different from EBLF in the Southern Hemisphere, but also different from EBLF elsewhere in the Northern Hemisphere. The southern part of East Asia was less affected by Quaternary glaciations, so the EBLF over this area has preserved many more ancient species than its counterparts of North America and Europe, and shows more remarkable biodiversity. Of course all of these forests are direct descendents of Tertiary evergreen forests.

The EBLF covers large parts of East Asia, including westward to 98°E longitude. Such a vast area of EBLF naturally shows variations due to different climate conditions, floristic composition and ecological characteristics. The north border of typical summer-rain EBLF in China coincides with the freezing isotherm for January and that of subtropical seasonal EBLF coincide with the 15℃ isotherm of mean minimum temperature of January. EBLFs of East Asia can be divided longitudinally into oceanic (Japan and Korea), moist-continental (eastern China), semi-moist continental (western China), and moist island sub-type (Taiwan).

In complexity, the EBLF is second only to tropical rainforests. The habitats of EBLF are enormously diversified, additionally due to human interference over a long period of time, which has greatly complicated the situation and led to the rise of many secondary characteristic and transitional communities. It is thus not easy to classify the EBLF. Until now there have been only two main approaches to vegetation classification, the eco-physiognomic and the floristic. The later can be divided further based on its focus on character species versus dominance types. Beard (1980) pointed out "It would seem that a desirable goal for the future should be the marrying of the two approaches into a single system of classification, wherein floristic units are combined by their structure into physiognomic units". We have accepted this idea and set up a classification scheme for EBLF; the higher-ranked units are based on physiognomy, and the median and lower units on species composition. At the same time the role of dominant species and diagnostic species is also considered (Song 2004). Such an integrative framework is needed in order to compare vegetation types over large, diverse areas.

References

Beard, J. S. 1980. The Physiognomic Approach. In: *Classification of Plant Communities* (R. H. Whittaker, ed.), pp 33-64. The Hague, Boston: Dr.W. Junk bv Publishers.

Box, E. O., Song Y.-Ch., A. Miyawaki, and K. Fujiwara 1991. An evergreen broad-leaved forest in transitional eastern China. *Bull. Inst. Environm. Sci. Technol. Yokohama Natl. Univ.*, 17(1):63-84.

Box, E. O., Ch.-H. Chou, and K. Fujiwara 1998. Richness, climatic position, and biogeographic potential of East Asian laurophyll forests, with particular reference to examples from Taiwan. *Bull. Inst. Environm. Sci. Technol., Yokohama Natl. Univ.*, 24:61-95.

Box, E. O. 2005. Vegetation Types and their Broad-Scale Distribution. In: *Vegetation Ecology* (E. van der Maarel, ed.), pp 106-128. Blackwell, Oxford.

Editorial Group for "Vegetation of Yunnan" 1987. [Vegetation of Yunnan.] Beijing: Scientific Press, 1024pp (in Chinese).

Ellenberg, H., and D. Mueller-Dombios 1967. Tentative Physiognomic-Ecological Classification of Plant Formations of the Earth. *Ber. Geobot Inst. ETH, Stiftg., Rübel Zürich,* 37: 21-55 (republished in Mueller-Dombois and Ellenberg 1974: Aims and Methods of Vegetation Ecology, pp 466-493).

Fujiwara, K. 1981~1986. [Phytosociological Investigation of the Evergreen Broad-leaved Forest of Japan, I~IV]. *Bull. Inst. of Environm. Sci. and Tech., Yokohama Natl. Univ.* 7(l): 67-133; 8(1):121-150; 9(1):139~160; 13(1):99-149 (in Japanese with English summary).

Hamilton, W. 1983. Cretaceous and Cenozoic history of the northern continents. *Annals Missouri Bot. Garden*, 70:440-458.

Hara, M., and Ch. Yonebayashi (eds.) 1997. *Lucidophyllous Forests in Southwestern Japan and Taiwan.* Natural History Research, special issue no. 4. Natural History Museum, Chiba. 173 pp.

Hattori, T., and S. Nakanishi 1985. On the distributional limits of the Lucidophyllous forest in the Japanese Archipelago. *Bot. Mag.* (Tokyo), 98:317-333.

He J. 1955. [Speaking on the subtropical rain forest zone of southeast China from the discovery of rain forest in Nanjing County, Fujian Province.] J. Xiamen University (Natural Sciience) **5**:31~41 (in Chinese).

Hsieh Chang-Fu et al. 1997. Floristic composition of the evergreen broad-leaved forests of Taiwan. *Nat. Hist.,*

Res., Special Issue No. 4:1-16

Jin, Zhenzhou 1979. Characteristics and types of evergreen broad-leaved forest in Yunnan. *Acta Botanica Yunnanica,* 1(1):90-105

Kira, T. 1954. New Classification of Climates in Eastern Asia as the Basis for Agricultural Geography. Hurl. Inst., Kyoto University (in Japanese).

Kira, T. 1991. Forest ecosystems of east and southeast Asia in a global perspective. *Ecol. Res.* 6:185-200

Lin Peng 1961. [Discussion on the distribution and terms of subtropical rainforest in Fujian.]

J. Xiamen University (Natural Science), 3(1):24-34 (in Chinese).
Miyawaki, A. (ed.), 1980-89. *Nippon Shokusei Shi* [Vegetation of Japan]. 10 vols, each about 400-700pp plus vegetation tables and color maps (in Japanese, with German or English summary). Shibundo, Tokyo.
Miyawaki, A. 1981. Das System der Lorbeerwälder (Camellietea japonicae) Japans. In: *Syntaxonomie* (H. Dierschke, ed.), pp 589-699. *Ber. Intern. Symp. Rinteln 1980.* Cramer, Vaduz.
Miyawaki, A. 1984. A vegetation-ecological view of the Japanese Archipelago. *Bull. Inst. of Environm. Sci. Tech., Yokohama Natl. Univ.* 11: 85-101.
Miyawaki, A., and T. Ohba 1963. *Castanopsis sieboldii*-Wälder auf den Amami-Inseln. *Scient. Reports Yokohama National University*, II(9):31-48.
Miyawaki, A., and S. Okuda 1990. [Vegetation of Japan Illustrated]. Tokyo: Shibundo, pp.800 (in Japanese).
Numata, M. 1987. Zonation and Conservation of Vegetation and Related Problems in Japan. In: *Vegetation Ecology and Creation of New Environments* (A. Miyawaki et al., eds.). Tokai University Press.
Numata, M., A. Miyawaki, and D. Itow 1972. Natural and semi-natural vegetation in Japan. *Blumea* 20(2):435-496.
Ohsawa, M. 1991. Structural comparison of tropical montane forests along latitudinal and altitudinal gradients in South and East Asia. *Vegetatio*, 97:1-10.
Ohsawa, M. 1995. Latitudinal comparison of altitudinal changes in forest structure, leaf type, and species richness in humid monsoon Asia. *Vegetatio*, 121:3-10.
Satoo, T. 1983. Temperate Broad-Leaved Evergreen Forest in Japan. In: *Temperate Broad-Leaved Evergreen Forests* (J. D. Ovington, ed.), pp. 169-189. Elsevier.
Shidei, T. 1974. Forcst Vegetation Zones. In: *The Flora and Vegetation of Japan* (M. Numata, ed.), pp 20-26. Kodansha and Elsevier.
Song Yongchang 1983. Die räumliche Ordnung der Vegetation Chinas. *Tuexenia*, 3:131-157.
Song Yongchang 1988a. The essential characteristic and main types of the broad-leaved evergreen forest in China. *Phytocoenologia*, 16(l):105~l23.
Song Yongchang 1988b. Broad-leaved evergreen forests in central Japan in comparison with eastern China. *Veröff. Geobot. Inst. ETH, Stiftung Rübel* (Zürich), 98:197~224.
Song Yongchang 1994. On the scientific term of the evergreen broad-leaved forest and their typology. In: *Studies of Vegetation Ecology* (Jiang Shu & Chen Changdu et al., eds), pp 189~199. Beijing: Scientific Press
Song Yongchang 1995. On the global position of the evergreen broad-leaved forests of China. In: *Vegetation Science in Forestry* (E. O. Box et al., eds.), pp 69-84. Kluwer.
Song Yongchang and Xu Guoshi 2003a. A scheme of vegetation classification of Taiwan, China. *Acta Bot.Sinica,* 45(8):883-895.
Song, Yongchang, Hsu Guoshi, Chen Weilie, Wang Xihua, Da Liangjun, and Chen Tiancai 2003b. Evergreen broad-leaved forest in Taiwan and its relationship with counterparts in mainland China. *Acta Phytoecologica Sinica,* 27(6):719-732.
Song, Yongchang 2004. Tentative classification scheme of evergreen broad-leaved forests of China. *Acta Phytoecologica Sinica,* 28(4):435-448
Su H. J. 1984. Studies on the climate and vegetation type of the natural forest in Taiwan. II: Altitudual vegetation zones in relation to temperature gradient. *Quart. J. Chin. Forest*, 17(4):57~73.
Suzuki, T. 1975. Die immergrünen Laubwälder Japans. *Phytocenologia*, 2(3-4):293-300.
Wang Chi-Wu 1961. *The Forests of China, with a Survey of Grassland and Desert Vegetation.* Maria Moors Cabot Foundation, Publ. no. 5. Harvard University, Cambridge (Massachusetts). 313 pp.
Whitmore, T. C. 1984. *Tropical Rainforests of the Far East.* 2nd edition. Clarendon Press, Oxford. 362 pp.
Wu Zhenyi (ed.) 1980. [Vegetation of China.] Beijing: Scientific Press. 1375pp.
Yim, Yang-jai 1977. Distribution of forest vegetation and climate in the Korean Peninsula. IV: Zonal distribution of forest vegetation in relation thermal climate. *Jap. J. Ecol.*, 27:269-278
Zhong Zhangcheng 1992. Study on the Ecosystem of Evergreen Broad-Leaved Forest. Chongqing: Southwest China Normal University Press. 438pp.
Zobel, D. B., and S. P. Singh 1997. Himalayan forests and ecological generalizations. *BioScience*, 47:735-745.

Community Groups and Canopy Dominance Types in the East Asian Laurel Forests
(from Song and Da, manuscript in preparation)

Community Groups	Dominance Types
Typical Laurel Forest	
1) Southeastern China	
Lithocarpus-Cyclobalanopsis	*Cycl. glauca*, *Castanopsis sclerophylla*, *Lith. glaber*
	Cyclobal. myrsinaefolia, C. gilva, C. sessilifolia
	Cyclobalanopsis stewardiana, C. gracilis
	Litsea coreana var. *sinensis-Lithocarpus harlandii*
	Cyclobalanopsis oxyodon, C. multinervis
	Quercus engleriana-Lithocarpus cleistocarpus
Schima-Castanopsis	*Schima superba, Castanopsis eyrei*
	Schima argenta, Castanopsis eyrei
	Castanopsis carlesii, Castanopsis fargesii
	Alniphyllum fortunei-Castanopsis tibetana
	Schima superba-Castanopsis fissa
	Castanopsis lamontii, Ca. fordii, Ca. fabri
	Castanopsis kawakami
	Altingia gracilipes, Altingia chinensis
	Gordenia acuminata-Cast. carlesii var. *spinulosa*
	Schima crenata-Castanopsis platyacantha
Cinnamomum-Machilus	*Machilus thunbergii*
	Cinnamomum subevenium, Cinnamomum japonicum
	Phoebe sheareri, Machilus leptophylla
	Phoebe bournei，*Machilus pauhoi*
	Machilus microcarpa, Phoebe zhennan
	Michelia maudiae
2) Southwestern China	
Castanopsis-Cyclobalanopsis	*Cyclobalanopsis glaucoides*
	Cyclobalanopsis delavayii
	Castanopsis orthacantha
	Castanopsis delavayii
Schima-Lithocarpus	*Lithocarpus craibianus*
	Lithocarpus echinophorus
	Lithocarpus echinotholus
	Lithocarpus xylocarpus
	Lithocarpus naiadarum
	Lithocarpus variolosus
3) Japan and Korea	
Lithocarpus-Cyclobalanopsis	*Lithocarpus glaber, Cyclobalanopsis glauca*
	Cyclobalanopsis acuta, C. salicina
	Cyclobalanopsis gilva, C. hondae
	Cyclobalanopsis myrsinaefolia, C. sessilifolia
Machilus thunbergii-Castanopsis	*Machilus thunbergii*
	Symplocos-Castanopsis sieboldii
	Schefflera-Castanopsis sieboldii
4) Taiwan	
Montane *Castanopsis-Cyclobalanopsis*	*Cyclobalanopsis morii, Castanopsis carlesii*
	Lithocarpus kawakami, *Cyclobalanopsis longinux*
	Cyclobalanopsis stenophylloides, Cy. sessilifolia

Subtropical Seasonal Evergreen BL Forest

1) Southeastern China	
Cryptocarya-Castanopsis	*Cryptocarya chinensis-Castan. hystrix, Cr. chinensis* *Cryptocarya concinna-Castanopsis tonkinensis*
Machilus-Beilschmiedia	*Machilus chinensis, Machilus nakao* *Beilschmiedia tsangii, Beilschmiedia fordii*
2) Southwestern China	
Lithocarpus-Castanopsis	*Castanopsis hystrix, Castanopsis indica* *Lithocarpus truncatus-Castanopsis fleuryi, C. fabrii.*
Machilus kurzii-Castanopsis	*Machilus kurzii, Castanopsis fargesii*
3) Taiwan	
Machilus-Castanopsis	*Lithocarp. amygdalifolius, Cyclobal. longinux* v. *koui* *Cryptocarya chinensis, Castanopsis uraiana* *Machilus japonica, Castanopsis carlesii* var. *sessile* *Turpinia ternata, Machilus japonica*
4) Southernmost Japan	
Ficus-Bischofia	*Turpinia ternata-Bischoffia javanica* *Ficus-Beilschmiedia erythrophloia*

Subtropical Ombrophilous Forest

1) Southeastern China	
Syzygium-Castanopsis	*Castanopsis hystrix, Castanopsis uraiana*
Ficus-Cleistocalyx	*Syzygium jambos-Cleistocalyx operculatus* *Ficus* spp., *Endospermum chinense* *Syzygium levinei, Aquilaria sinensis*
2) Taiwan	
Ficus-Machilus	*Ficus septica-Ficus irisana* *Ficus fistulosa-Machilus japonica* var. *kusanoi* *Beilschimiedia tsangii-Castanopsis stellato-spina*

c. Subtropics and tropics

Kazue Fujiwara (*Graduate School of Environment and Information Sciences, Yokohama National University, Yokohama, Japan*)

Basically, the subtropics and tropics include southern China and Southeast Asia below about 30° N latitude, though the distinction is made less clear by the influence of complex topography. Vegetation types can be classified in general as tropical, subtropical and temperate. Generally, deciduous *Quercus* forests are good indicators of the temperate zone but change southward to subtropical secondary types (*Malotus*, *Ficus*, *Trema*, etc.) and tropical secondary types (*Macaranga*, *Trema*, *Combretum*, *Dillenia*, etc.). Broad-leaved evergreen forests include subtropical evergreen forests (see III. b. 5), which have species compositions similar to those of tropical mountain forests, with evergreen *Quercus* (*Cyclobalanopsis*), *Lithocarpus*, *Castanopsis*, *Litsea, Beilshmiedia*, *Phoebe, Schefflera, Elaeocarpus*, *Psychotria,* etc. Such broad-leaved evergreen forests can be seen especially in tropical mountains on the integrated vegetation map. Most of the warm-temperate area is developed and broad-leaved evergreen forests have disappeared, except in protected areas such as national parks and forest preserves.

On the other hand, tropical rainforests have mostly disappeared due to deforestation for timber and for land uses such as cultivation and tree plantations. After cutting and burning, most of the former forest area of northern Southeast Asia has changed to tropical deciduous forests or woodlands, such as dry dipterocarp forests.

Tropical deciduous forests occur in northern Southeast Asia, over most of lowland Thailand, in southern Laos, and in Cambodia, Viet Nam and Myanmar, up to elevations of 800-1000m. Natural tropical semi-evergreen forests also occurred in this region (Whitmore, 1984), but we cannot see them any more except at Sakaerat in Thailand (Fujiwara, 1994). Most wooded areas in lowland central and northern Thailand are now constituted by tropical dry forests such as dry dipterocarp forest (Santiesk, 1988). Nowadays, most people and even scientists in Thailand believe that dry dipterocarp forests are natural forests in Thailand, based on soil conditions and the monsoon climate. These forests occur at 10-20° N latitude.

The northern part of Southeast Asia has a six-month dry season, with annual rainfall of 1000-1500 mm. The rainfall comes mainly as showers, from May to October. The soil is also dry. Light yellow-brown soil covers this region (dry laterite and also nutrient-poor sandstone).

Good examples of natural semi-evergreen forest and dry dipterocarp forest, the latter as secondary forest in an area of potential tropical semi-evergreen forest (Whitmore 1984), were surveyed in 1978 by Fujiwara et al. and in1994-1996 by Fujiwara, Kawla-ierd, Tejajati and Santiesk. Dry dipterocarp forest in Laos was surveyed in 2007 by Fujiwara, Box, Mochida, and members of the National University of Laos. Tropical semi-evergreen forests have also been called dry evergreen forest (Royal Forestry Department 1962). The forest structure is five layers, with super canopy (ST), canopy (T1), sub-canopy (T2), shrub (S), and herb (H) layers. The super-canopy (emergent) layer is approximately 30-50 m high, the canopy layer 15-40 m, sub-canopy layer 5-15 m, and the shrub layer 0.8-5 m. Plant cover is variable: ST: 5-30%, T1: 40-70%, T2: 30-50%, S: 60-70%, and H: 10-30%

(Kawla-ierd, 1997). The chracteristic species of dry evergreen forest in Sakaerat are *Hopea ferrea*, *Memecylon ovatum*, *M. caeruleum*, *Walsura trichostemon*, *Randia witti*, *Shorea henryyana*, *Irvingia malaya*, etc. The tropical deciduous forests, such as dry dipterocarp forest, are not tall: T1: 15-23m, T2: 12-16m, S: 4-6m, and H: 0.6-1m. *Arundinaria pusilla* covers the understorey with 40-70% cover. The vegetation cover by layer is roughly T1: 10-30% (occasionally 60%); T2 20-50% (occasionally 70%); S: 20-50%; and H: 50-70%. Characteristic species of dry dipterocarp forest are *Shorea obtusa*, *S. siamensis, S. roxburgii*, *Dipterocarpus obtusifolius*, *Pterocarpus macrocarpus*, *Sindra siamensis*, *Xilia xylocarpa*, *Cycas siamensis*, etc. Most plants are fire-resistant and have thick bark to protect the cambium, plus thick, coriaceous (leathery) leaves. Ground fire in Sakaerat occurs at intervals of 1-3 years and aids seedling establishment by burning off the *Arundinaria pusilla* and by releasing nutrients.

References

Fujiwara, K. 1987. Rehabilitation of tropical forests from countryside to urban areas. In: Lieth, H. and Lohman, M. (eds.): *Restoration of tropical forest ecosystems*. pp. 119-131. Kluwer Academic Publishers.

Kawla-ierd, S. 1997. Restoration of degraded areas of tropical forest ecosystems in Thailand. Doctoral thesis of Graduate School of Engineering. Yokohama National University. 166 pp.

Royal Forest Department 1962. Types of forest of Thailand. Report No. 44. 12pp.

Santisuk, T. 1988. An account of the vegetation of northern Thailand. Geobotanical Research vol. 5. Frantz-Steiner-Verlag, Wiesbaden-Stuttgart. 101 pp. +75 figures.

Whitmore, T. C. 1984. *Tropical rain forest of the Far East.* Oxford University Press. 352pp. Oxford.

d. **Mangrove vegetation: composition, distribution, disturbance and restoration**.

Yukira Mochida (*Yokohama National University, Yokohama, Japan, mochida@edhs. ynu.ac.jp*)

Mangroves are largely confined to the regions between 30° north and south of the equator, with notable extensions beyond this northward to Bermuda (32° 20′ N) and Japan (31° 22′ N) and southward to Australia (38° 45′ S), New Zealand (38° 45′ S) and the east coast of South Africa (32° 59′ S). Within these confines mangroves are widely distributed, but their latitudinal development is restricted along the western coasts of the Americas and Africa, as compared to the equivalent eastern coasts. In the Pacific Ocean, natural mangrove communities are limited to the western side, and they are absent from many Pacific islands (Spalding et. al., ed., 1997).

In Southeast Asia, including the Philippines, Vietnam, Thailand, Malaysia and Myanmar, the relationship of the floristic composition to the mangrove zonation, sediment type, major land use and location has clarified the mangrove ecosystems. Mangrove habitats were of three types: estuary-delta type, backmarsh-lagoon type, and coral reef-tidal flat type. Mangrove vegetation of the estuary-delta type in the Malay Peninsula was classified phytosociologically into six community types: (1) a *Sonneratia alba-Avicennia alba* community, (2) a *Rhizophora apiculata* community, (3) a *Rhizophora apiculata-Bruguiera* spp. community, (4) a *Ceriops tagal-Xylocarpus* spp. community, (5) a *Lumnitzera littoralis* community, and (6) an *Excoecaria agallocha* community. These six community types were arranged from the marginal lower part to the upper part of the estuaries, and were correlated to the level of the tidal zone and to the sediment types.

In addition, the Ayeyarwady (Irrawaddy) delta in Myanmar was classified phytosociologically into 10 community types: (1) an *Avicennia alba* community, (2) an *Avicennia marina* community, (3) a *Rhizophora apiculata* community, (4) a *Bruguiera cylindrica* community, (5) a *Bruguiera* spp. community, (6) a *Heritiera fomes* community, (7) an *Excoecaria agallocha* community, (8) a *Sonneratia caseolaris* community, (9) a *Ceriops decandra* community, and (10) an *Avicennia officinalis* community. The ten community types were found from the marginal lower part to the upper part of the tidal range. These types were influenced by sedimentary environment and human impacts.

The results of reforestation show that low survival rate and poor growth of the trees can be attributed both to ground level and to biotic disturbances. The growth of trees on low ground is obviously better than that of trees on high ground. On low ground, *Sonneratia apetala* demonstrates the best growth and *Rhizophora apiculata* has the highest survival rate; on high ground, though, the survival and growth rates of *Avicennia officinalis* are the best. All the species planted show their largest increments of tree height from the middle of the rainy season (June and July) to the beginning of winter (November). In natural forest, *Aegiceras corniculatum*, *Bruguiera sexangula* and *Ceriops decandra* show a tendency to grow slowly, and their regeneration fluctuated yearly. The average yield per hectare and its increment in natural forest are 32.21 m^3 and 4.1 m^3, respectively. Annual consumption of mangrove wood was 993,819 m^3 in the Ayeyarwady delta. The total productivity of natural forest and of plantations was only 662,662 m^3 per year. Thus there is a wood deficit caused by overexploitation of both mangrove communities in the delta. These findings can be applied to develop an appropriate management system optimizing economic and ecological equilibrium for the conservation and restoration of mangrove forests in Myanmar.

On the other hand, Bohol Island in the Philippines suffers from strong human impact (deforestation and *Nypa* plantation). The mangroves were divided into two community types, an *Avicennia marina-Rhizophora apiculata* community and a *Nypa fruticans* community. Each community type was divided into four sub-units.

e. Grassland and Steppe Vegetation

Irina Safronova (*Komarov Botanical Institute of Russian Academy of Sciences, St.-Petersburg, Russia)*

Within Asia extensive areas are occupied by steppes (grasslands), which develop in dry temperate climatic zones. Steppe vegetation embraces plant communities mainly consisting of frost-resistant, xerophilous, perennial herbaceous plants, mostly bunch grasses of the genera *Stipa*, *Festuca*, *Agropyron*, *Cleistogenes*, *Helictotrichon*, *Koeleria*, *Poa*, etc. In various ecological environments, plant communities of also involve other biomorphs: tufted sedges (*Carex humilis, C. pediformis*), onions (geophytes), non-graminoid herbs (i.e. forbs, of genera *Galatella, Linosyris, Tanacetum*, etc), dwarf semi-shrubs (genera *Artemisia, Thymus,* etc) and shrubs (of genera *Amygdalus, Caragana, Spiraea*, etc.) (Lavrenko 1956; Lavrenko, Karamisheva & Nikulina, 1991).

The Eurasian Steppe Region occupies an area about 8,000 km long, from the Lower Danube (27° E) in the west to the Shungari river in Manchuria (128° E), in the east. In Western Siberia the northern limit of grassland reaches 55° N; its southern limit runs approximately along 48° N and extends south to 40° N in China on the Loess Plateau.

A common feature of the climate is its high degree of continentality, increasing to the east. Summer is warm and dry, with mean July temperature 20-25°C. Daytime temperature in summer may reach 35°. Winter is cold and long, with mean January temperature -10° to -16° C, sometimes as low as
-30° to -40°. Yearly precipitation is 250–400 (450) mm, which is less than helf the yearly potential evapotranspiration. Maximum precipitation falls in summer, and this distribution is characteristic of the whole steppe region. Precipitation is irregular and droughts are common, occurring every second or third year. The annual snow cover is 10 to 30 cm. Soils freeze more or less deeply depending on the scarcity of snow and the degree of winter cold.

The eastern part of the steppe region is significantly more continental than the western part. In particular, the east has less precipitation (in the Trans-Baikal region locally only 160 mm), lower yearly temperature, a shorter vegetative period, colder and longer winter, and a sharp transition from cold to warm in spring.

As seen from the above, climatic conditions change within the steppe region both from north to south and from west to east. Zonal (latitudinal) and meridianal (longitudinal) changes of soil and vegetation cover follow accordingly (Lavrenko 1956; Karamysheva & Rachkovskaya 1973; Karamysheva 1993; Ogureeva, 1999; Safronova et al., 1999).

From north to south, the zonal soil changes from chernozem (black earth), to dark chestnut, chestnut, and finally light chestnut soil. Various kinds of chestnut soils prevail. Soils are diverse not only by their types but also by development (normal, saline, eroded, weakly developed), by content of humus or salt, and by texture (loamy, sandy loam, sandy, etc).

Many Russian scientists contributed greatly to the study of steppes, but the works of the great phytogeographer/academician Evgeni Lavrenko are especially significant. His subzonal and regional division of the Eurasian steppe region is still generally recognized and used now (Lavrenko 1970).

Changes of vegetation cover from north to south permit subdivision of the Eurasian steppe region into latitudinal strips (subzones). In the northern subzone, forb-rich steppe communities prevail, dominated by *Stipa* species on the southern chernozem and dark chestnut soils. *Stipa zalesskii* dominates on the loamy soils and co-dominates on other soils. *Stipa capillata* covers the sandy-loamy soils, *Stipa pennata* grows on sandy soils, and *Stipa lessingiana* and *S. korshinskyi* on carbonate soils.

Co-dominants are compact bunch grasses (*Stipa tirsa, S. dasyphylla, S. pulcherrima, Festuca valesiaca, Koeleria cristata*) and rhizomatous grasses (*Pleum pleoides, Poa angustifolia, Calamagrostia epigeios*). Perennial forbs (*Medicago romanica, Astagalus onobrychis, Oxytropis pilosa, Onobrychis arenaria, Fragaria viridis, Filipendula vulgaris, Galium verum, Hieracium echioides, Pulsatilla multifida, Salvia stepposa, Peucedanum morisonii, Seseli ledebourii*) and the sedge *Carex supina* are abundant. There are also dwarf semi-shrubs – *Artemisia marschalliana, A. austriaca, A. dracunculus*, and *Jurinea multiflora*. Short vegetating plants are not usual here.

In the northern steppe subzone, solonez and solonchak soils occur locally, occupying not so large areas. On solonetz one can find communities of *Festuca valesiaca,* where *Crinitaria villosa* and *Artemisia austriaca* are often abundant. Characteristic of solonetz substrates are communities of *Artemisia nitrosa* with the participation of *A. lerchiana, A. austriaca,* and *Tanacetum achilleifolium.* On solonchaks there are communities of *Kalidium foliatum*, of *Halimione verrucifera*, and of *Salicornia europaea* .

To the south, the forb-grass steppes change to more xerophilous bunch-grass steppes on chestnut soils. Communities of *Stipa lessingiana* occur most widely, in various environments, whereas communities of *Stipa capillata* prevail on sandy-loamy soils, those of *Stipa pennata* on sandy soils, coenoses of *Stipa sareptana* on saline soils, coenoses of *Stipa korshinskyi* on carbonate soils, and coenoses of *Stipa zalesskii* in places with additional moisture. Co-dominant in all communities is *Festuca valesiaca* (with the exception of coenoses on sandy soils, where *F. beckeri* participates). The permanent components are compact bunch grasses (*Stipa lessingiana, Koeleria cristata,* and *Agropyron desertorum* on loamy soils, and *Agropyron fragile* and *Koeleria glauca* on sandy soils and sands) and the sedge *Carex supina*. On saline soils the obligatory component is the long-rhizomatous grass *Leymus ramosus.* Forbs are less abundant than in the northern steppes and include more xerophilous species, such as *Crinitaria villosa, Dianthus leptopetalus, Galium ruthenicum, Potentilla humifusa, Serratula xeranthoides, Tanacetum achilleifolium*, etc., and on sands, *Achillea gerberi, Astragalus virgatus, Euphorbia seguieriana, Scorzonera ensifolia*, etc. Dwarf semi-shrubs are represented by not so many species, but they are rather abundant locally – *Artemisia austriaca, A. lerchiana, A. lessingiana, A. marschalliana, A. pauciflora, Jurinea multiflora, Kochia prostrata,* and *Atriplex cana*. Ephemeroids (mini-geophytes) play a more noticeable role, especially *Poa bulbosa, Tulipa biebersteiniana*, and *T. biflora.*

Sites with saline soils and solonetz are occupied by communities of *Festuca valesiac,* with the participation of *Psathyrostachys juncea*, and *Kochia prostrata*; communities of *Artemisia lerchiana* have coenoses of *Tanacetum achilleifolium.* Crusted solonetz carries communities of *Artemisia pauciflora* with *Atriplex cana*.

Further southward, dwarf semi-shrub/bunch-grass steppes cover the light chestnut soils. These steppes are the most xerophitic (Safronova, 2005 a, b). Their obligatory components are xerophilous dwarf semi-shrubs, mostly of genus *Artemisia* subgenus *Seriphidium,* but bunch grasses prevail. *Stipa sareptana* is the most characteristic for this subzone, forming communities in various environments. Communities of *S. lessingiana* are connected with carbonate soils, communities of *S. capillata* with sandy-loam soils, and communities of *S. pennata* with sandy soils. The dwarf semi-shrub/bunch-grass steppes are considerably poorer in species than the others. Characteristic for them are also bunch grasses *Festuca valesiaca* and *Agropyron desertorum*; on loamy soils *A. fragile*; on sandy-loam soils the rhizomatous grass *Leymus ramosus*; and on saline soils dwarf semi-shrubs (*Artemisia* spp., *Camphorosma monspeliaca, Kochia prostrara*, *Tanacetum achilleifolium*, and *Jurinea multiflora*,) and xerophilous herbs (*Astragalus testiculatus, Cachrys odontalgica, Crinitaria tatarica, Dianthus leptapetalus, Ferula caspica, Limonium sareptanum, Palimbia rediviva, Serratula xeranthemoides*, and *Trinia hispida*). The roles of ephemeroids (*Poa bulbosa, Tulipa biebersteiniana, T. biflora*) and annual plants are more noticeable. Solonez substrates are covered by the dwarf semi-shrubs communities, with *Artemisia pauciflora, Camphorosma monspeliaca, Atriplex cana, Anabasis aphylla, A. salsa*, and *Nanophyton erinaceum.*

Within each subzone, the diversity of plant communities and number of their ecotypes depend on various environmental factors, first of all soils and substrates, and on the ecological ranges of the edificators (main plant structural elements).

So, *Stipa zalesskii* has its phytocoenotic optimum in the northern subzone, *Stipa lessingiana* in the middle, and *Stipa sareptana* in the southern subzone. They form communities also in other subzones, but their ecological range is less there, for they occur both on soils with light mechanical composition and on stony or saline substrates.

Steppes of *Helictotrichon desertorum, Stipa pennata* and *S. capillata* occur in all subzones, but the first is restricted to a petrophytic ecotype only, and the two last to psammophytic or petrophytic situations. Comminities of *Stipa sareptana* as well as *Festuca valesiaca* are also indicators of disturbed habitats. These also occur on saline soils and substrates (Ivanov 1958; Isachenko & Rachkovskaya, 1961; Safronova 2003).

In Central Asia, steppes of *Stipa krylovii* are widely distributed and steppes of *S. baicalensis* and *S. grandis* also occur. The almost permanent component of these steppes is the dwarf semi-shrub *Artemisia frigida*. Locally the rhizomatous grass *Leymus chinensis* also plays a great phytocoenotic role.

Endemic desert-steppes have no analogues in other parts spreading on the southern outskirt of Central Asia (Yunatov 1950, 1974). These include communities of *Stipa glareosa*, *S. gobica, S. klemenzii* and *Allium polyrrhizum.* Dwarf semi-shrub saltworts *Anabasis brevifolia, Salsola passerina*, and *Reamuria soongorica* grow on the most strongly salinized substrates.

References

Isachenko, T. I., and E. I. Rachkovskaya 1961. [Main zonal types of the Northern Kazakhstan steppe]. Proceedings BIN AS USSR, ser. 3: Geobotany (Leningrad), no. 13, pp 133-397 (in Russian).

Ivanov, V. V. 1958. [*Steppe of West Kazakhstan, in connection with its Dynamics*]. Moscow, Leningrad. 288pp (in Russian).

Karamysheva, Z. V. 1993. [Botanical geography of Eurasian steppes]. In: [*Steppes of Eurasia: problems of conservation and reconstruction. For memory of E. M. Lavrenko*], pp 6-29. St.-Petersburg, Moscow. (In Russian)

Karamysheva, Z. V., and E. I. Rachkovskaya 1973. [*Botanical geography of the Central Kazakhstan*

Steppe Region]. Leningrad. 278pp (in Russian).

Lavrenko, E. M. 1956. [Steppes and agricultural ground in place of steppes]. In: [Vegetation cover of the USSR]: Explanatory text to "[Geobotanical Map of the USSR], scale 1 : 4 000 000. Moscow, Leningrad. Vol. 2, pp 595–730 (in Russian).

Lavrenko, E. M. 1970. [Provincial subdivision of the Pontic-Kazakhstan subregion of the Eurasian steppe region]. Botan. Zhurnal (Leningrad), 55(12):609-625 (in Russian).

Lavrenko, E. M., Z. V. Karamysheva, and R. I. Nikulina 1991. [Steppes of Eurasia]. Leningrad. 146pp (in Russian).

Ogureeva, G. N. (ed.) 1999. [Zones and types of altitudinal-belt vegetation of Russia and neighbouring countries, for high school]. Scale 1 : 8 000 000 (2 sheets). Moscow. (In Russian)

Safronova, I. N, T. K. Yurkovskaya, I. M. Mikljaeva, and G. N. Ogureeva 1999. Zones and types of Altitudinal-belt vegetation of Russia and neighbouring countries. Explanatory text and legend to map. Moscow. 64pp (in Russian & English).

Safronova, I. N. 2005. Ecological classification of steppe and desert vegetation for the European Vegetation Map. In: *Application and Analysis of the Map of the Natural Vegetation of Europe* (U. Bohn et al., eds.), pp 151-161. Bonn.

Safronova, I. N. 2005a. [Desert Steppes of the Lower Volga Region]. *Volga Ecol. Journal* (Saratov),, 3: 262–268 (in Russian).

Safronova, I. N. 2005b. [Phytocoenotic diversity of desert steppes of the Pontic-Kazakhstan subregion of the Eurasian steppe region]. In: *Problems of Steppe Investigation* (Orenburg), 5:19-27 (in Russian).

Yunatov, A. A. 1950. [Main features of the Vegetation Cover of the Mongolian National Republic]. Proceedings of Mongolian Committee. No. 39. Moscow, Leningrad. 223 pp (in Russian).

Yunatov, A. A. 1974. [Desert Steppes of the Northern Gobi in the Mongolian National Republic]. [Biological Resources and Environment of Mongolia]. Vol. 4. Leningrad. 132 pp (in Russian).

e. Semi-desert and desert vegetation

Elgene O. Box (Department of Geography, University of Georgia, Athens, Groegia, USA)

The present-day geologic and physiographic structure of Asia is centered on the Himalayan Mountains and Tibetan Plateau. A mountain node also exists at the western end of the Himalaya, from which other major mountain ranges radiate in various directions. The most important of these is the Tien Shan-Altai system, which extends to the north-northeast into Mongolia, dividing the dry, temperate interior of Asia into:

1) a western part, called Middle Asia in Russian literature (essentially Turkestan and the Turanian Basin), influenced far inland by westerly winds from the Mediterranean; and

2) an eastern part, called Central Asia (essentially the Tibetan plateau and northwestern China, plus Mongolia) dominated by the Asian monsoon system.

This dry region of interior Asia also includes the Asian portion of the temperate grassland corridor that extends from the Ukraine to Mongolia and northern China. These temperate grasslands range from tall meadow-steppes in the north to drier, open steppes in the south, following the north-south moisture gradient which obtains across most of the continent. These steppes eventually grade southward into the temperate semi-deserts and deserts.

The desert region in our study area lies almost entirely in Central Asia, i.e. east of the Tien Shan and Altai barriers. This dry region includes the Tien Shan region of central Xinjiang, Kashgaria and the Tarim Basin (in southwestern Xinjiang), and Gansu and western parts of Inner Mongolia (e.g. Ala-Shan Mountains), as well as Dzungaria, which forms the transition from Middle Asia to Central Asia. Tibet is also dry but is considered separately.

Of course the vegetation of Central Asia is closely related to that of Middle Asia and even of the Middle East. For regional vegetation descriptions, one might consult the following.

General:	Archibold (1995), Walter (1968, 1973, 1974, 1985)
Dry regions:	Breckle (1983), Davis et al. (1971), Freitag (1971), Korovin (1961-62), Petrov (1966-67), Popov (1940), Walter & Box (1983), Yunatov (1950), Zohary (1974)
Mountains:	Chang (1983), Chen et al. (1986), Troll (1972).

Deserts (*sensu strictu*) have essentially no vegetation, while semi-deserts have scattered plants. Desert conditions may have existed since the earlier Paleozoic (e.g. Glennie 1987). Whether the desert flora arose this early, or in the Miocene (expanding during the colder, drier Pliocene and Pleistocene, as suggested by Axelrod 1958), the desert flora of Asia has probably been closely related to that of northern Africa for a long time. Total species richness is low and there are essentially no true native stem-succulents, but the vegetation of the Middle Eastern deserts shows a wide variety of adaptations of form and seasonality to avoid dehydration and maintain active metabolism (cf. Walter 1973, pp. 693, based on Zohary). Some dwarf-shrubs are evergreen but greatly reduce their leaf area at the beginning of the dry season (e.g. *Artemisia monosperma, Reaumuria palestina, Salsola villosa, Suaeda palestina, Zygophyllum dumosum*). Some are wintergreen shrubs, losing their leaves in summer (e.g. *Lycium arabicum, Anagyris foetida*), while some (generally dwarf-shrubs) shed their leaves but retain evergreen stems, as in *Retama* and *Calligonum* species. Some have rather grayish, soft, deciduous leaves but keep smaller leaves during the summer (e.g. *Artemisia herba-alba*). Some are totally leafless, like *Ephedra*. Perhaps most interesting are the leafless shrubs and arborescents with modular stems and green, photosynthetic but disposable bark segments, e.g. *Haloxylon persicum* and *Anabasis articulata*. Where more water is available, there may be scattered trees such as acacias, deciduous thorn-shrubs such as *Noaea*, or desert grasses such as *Aristida*. Many of these desert taxa extend well into Middle and even Central Asia.

The climates of the temperate deserts in Central Asia are warm to hot in the summer and severely cold in the winter. Precipitation is confined almost completely to summer, brought by monsoon storms which manage to penetrate into the continental interior. Soils in all regions are coarse and skeletal, salinized in areas of internal drainage. The Central Asian deserts are totally continental and separated from the subtropical deserts of southwestern Asia, although they may share many genera and some species.

Our fieldwork in the dry region of Central Asia was confined to western China, at the following locations:

- desert vegetation and montane forests of Dzungaria (Xinjiang, June 2005);
- semi-desert vegetation of Kashgaria and the Tarim Basin (Xinjiang, July 2005); and
- montane deciduous and conifer forests of dry-climate Gansu (July 2006);

as well as (from earlier work):

- steppe with pine-forest outliers in eastern Inner Mongolia (July 2000); and
- steppe and dry montane forests in western Inner Mongolia (July 2002).

We were, however, also able to make a brief stop in the Tuva Republic of southwestern Siberia, in the dry steppe/semi-desert area south of the Sayany Mountains near Kyzyl. This area represents another transition between Middle Asia and summer-rain Central Asia.

Local taxonomic assistance was less available in the dry areas, so our data-base consists only of a small number of relevés from Dzungaria and the Tarim Basin (2005), from montane forests of Gansu (2006), and from dry steppe and semi-deserts of Inner Mongolia (2002) and the Tuva area (2007). We do not have enough data to do formal phytosociological analyses, but we could understand the environmental relationships.

Dzungaria extends across northernmost Xinjiang Province of western China, east of the Dzungarian Gate, which represents a gap in the Tien Shan-Altai mountain system. This corridor between Middle Asia and the Gobi, as well as the Gobi itself, represents a region of rockier substrates and deserts dominated by desert shrubs and dwarf-shrubs such as *Anabasis*, *Calligonum* and *Haloxylon persicum*, sometimes with *Stipa* bunch grasses. Smaller, more extremely xeromorphic dwarf-shrubs included *Salsola*, whitish-gray *Astragalus*, *Atraphaxis* (Polygonaceae, with minute oval leaves), and both green and whitish species of *Artemisia*. Isolated trees of *Populus, Tamarix* and occasionally *Haloxylon* may occur along streams. The most widespread green landscapes seemed to be *Calligonum* and *Haloxylon* shrub-steppes, where sandier substrates occurred. On the other hand, enormous areas were dominated by a sandy rubble desert with only sparse herbs and small dwarf-shrubs and semi-shrubs.

Ürümchi, the Xinjiang capital, is at about 900m elevation on the north slope of the Tien Shan. There is essentially no groundwater on the slopes or uplands, so there is essentially no vegetation except small bushes in ravines. In the Turpan Basin to the east (and south of the easternmost Tien Shan) there is almost no vegetation at all over very large areas. One part of this area falls below sea level and represents the hottest part of the Central Asian desert. Even so, the area around Turpan is ingeniously irrigated with mountain runoff water (via underground ducts) and produces food.

In the Tarim Basin to the southwest, the Takla Makan desert is a large sand sea within the horseshoe of mountains (open to the east) formed by the Tien Shan on the north, the Pamirs in the center, and the Karakoram and Kunlun ranges on the south. Together these ranges form one of the most effective rain shadows in the world, and precipitation is very rarely recorded in the Tarim Basin. Rubble desert appears at the western end of the Tarim Basin, near the dry mountains, with *Salsola*, *Calligonum*, and occasional patches of *Halocnemon*. Despite the dry appearance, however, runoff from the mountains (on all sides) does generate intermittent and permanent streams that extend into the Tarim Basin. Along these streams one can find riparian strips of the phreatophytic *Tamarix ramosissima* as well as the widespread *Populus diversifolia*, *P. euphratica*, and *Ulmus pumila*. In some areas there are even extensive marshes of *Phragmites, Typha*, and *Scirpus* species. There is little vegetation on the areas of mobile sand, but extensive efforts are underway to stabilize the sands with plantations of native desert shrubs, especially *Haloxylon persicum, H. ammodendron*, and *Calligonum*. In natural stands, these large shrubs grow continually upward, above the rising surface of mobile sand, until it then shifts again and the shrubs are left on top of pedestals called nebkhas.

One characteristic of the sandy deserts is the dominance of both typically small and much larger xeromorphic shrubs, some of them leafless and some at least partly evergreen. Reaching 2 m in height, leafless *Haloxylon persicum* extends over the whole region and even over into the Gobi desert. In the deep-sand Kara-Kum desert of Middle Asia, *H. ammodendron* can become a leafless tree reaching 8m in height. This is the only cold-winter desert region in the world in which a tree form gains even local dominance. Other important desert shrubs, especially in Middle Asia, include *Artemisia pauciflora*, *A. terrae-albae, Halostachys caspica, Anabasis salsa, Halocnemum strobilaceum*, and *Kochia prostrata*, along with steppe and desert grasses such as *Festuca sulcata, Stipa capillata, Koeleria cristata*, and *Agropyron repens*. In areas of flat terrain and finer soil, mini-geophytes such as *Poa bulbosa* form vernal carpets of miniature flowers (see Walter 1974, p. 254).

The Tibetan Plateau (average elevation around 4000 m) is a region of dry steppes, alpine mats (especially of *Kobresia* species), dwarf conifer scrub of *Juniperus* and *Sabinia*, and other sparse, low-growing, often cushion-shrub vegetation adapted to harsh conditions. Many familiar genera from Central Asia (and Middle Asia) are represented, including *Caragana, Reaumuria, Acantholimon, Astragalus, Tanacetum, Artemisia, Ptilagrostis*, and *Festuca*. Some species even reach the higher elevations, including *Eurotia ceratoides* and *Kochia prostrata*. East Asian elements are important only in the east but include *Gentiana, Primula, Saxifraga, Saussurea*, and *Rhododendron*, among others. Holarctic elements are few, but some are very abundant, especially in the alpine mats and marshes: *Kobresia, Carex, Heleocharis, Eriophorum*, and *Juncus*. Where moisture permits, subalpine tall-forb stands (as in the Russian Far East) include such genera as *Aconitum, Delphinium, Ligularia, Polygonum* and *Rheum*. These different geoelements all represent taxa that migrated into Tibet after the last Pleistocene glaciations. The vegetation of Tibet is especially well summarized by Chang (1983; see also Chen et al. 1986, Troll 1972, Walter 1974, Wu 1980).

Pine forests cover extensive lowland areas in Asia but also occur in mountains of dry regions, especially after soil erosion following cutting. In southwestern China, forests of *P. armandii* occur in Sichuan and on the Yunnan plateau. In addition to pine, "Chinese fir" (*Cunninghamia lanceolata*) is important in secondary landscapes and is widely planted. In the Tien Shan and Altai systems, the montane conifer forests are simpler, dominated often by *Picea schrenkiana* (as in Middle Asian mountains). We found such a forest of *P. schrenkiana* at 1800m in the Tien Shan above Ürümchi, growing on a dry slope where one would never have thought spruce possible. In more moist situations, though, montane and subalpine forests may include shade-tolerant *Pinus sibirica*, as well as boreal *Picea* and *Abies*, larches, and *Pinus sylvestris* (see Walter 1974; cf. Walter & Box 1983: chapter 7). In the Altai Mountains of northernmost Xinjiang, near the Kazakh and Mongolian borders, we found extensive montane forests (1500-1800m) of *Picea obovata* with *Larix sibirica* and occasional *Abies sibirica*.

Wetlands in dry regions include marshes and inland deltas, but also swamps, bogs, and (*sensu lato*) even lakes and streams. Most wetlands are highly productive systems when not badly degraded, have important economic and social benefits for local human populations, and perform useful ecological services such as cleansing wastewater. Wetlands also support a wide range of animal life, often far beyond their own borders. Most important in drier climates are probably the freshwater marshes which are critical for birds migrating between wintering areas in tropical Asia and summer breeding grounds in Siberia. Such marshes may occur in depressions as well as along streams, especially in the deserts of western China, the grasslands of northern China and Mongolia, and in Middle Asia and the highlands of Tibet. These marshes are composed primarily of reeds (*Phragmites*), cattails (*Typha*), sedges (*Cyperus, Scirpus, Carex*) and similar herbaceous plants. If seasonal pools form, small marshes of sedges and reeds occur. Halophytes include species such as *Halocnemum strobilaceum* on very saline sites and *Nitraria retusa* in brackish water. Deciduous but otherwise juniper-like tamarisk trees (*Tamarix* spp.) also occur where groundwater can be reached, generally at greater depth.

References

Archibold, O. W. 1995. *Ecology of World Vegetation*. Chapman and Hall, London. 510 pp.

Axelrod, D. I. 1958. Evolution of the Madro-Tertiary flora. *Botanical Review*, 24:433-509.

Box, E. O. 1995. Global and local climatic relations of the forests of East and Southeast Asia. In: *Vegetation Science in Forestry* (E. O. Box et al., eds.), pp. 23-55. Dordrecht.

Box, E. O. (ed.), with R. K. Peet, T. Masuzawa, I. Yamada, K. Fujiwara and P. F. Maycock (co-eds.) 1995. *Vegetation Science in Forestry: Global Perspective based on Forest Ecosystems of East and Southeast Asia*. Kluwer, Dordrecht. 663 pp.

Breckle, S. W. 1983. Temperate Deserts and Semi-Deserts of Afghanistan and Iran. In: *Temperate Deserts and Semi-Deserts* (N. West, ed.), pp. 271-319. Elsevier, Amsterdam.

Chang D. H. S. 1983. The Tibetan Plateau in relation to the vegetation of China. *Ann. Missouri Bot. Gard.*, 70:564-570.

Chen L.-Zhi, Chang Hs.-Sh., and Committee 1986. *Proceedings of the International Symposium on Mountain Vegetation*. Beijing: Botanical Society of China. 297 pp.

China Natural Geography Editorial Committee (eds.) 1984. (*China Natural Geography: Climate.*) Academia Sinica. Science Press, Beijing. 161 pp. (in Chinese).

Davis, P. H., P. C. Harper, and I. C. Hedge 1971. *Plant Life of South-West Asia*. Botanical Society of Edinburgh. 335 pp.

Freitag, H. 1971. Die natürliche Vegetation Afghanistans. *Vegetatio*, 22:285-344.

Glennie, K. W. 1987. Desert sedimentary environments, present and past – a summary. *Sedimentary Geology*, 50:135-165.

Korovin, E. P. 1961-62. (*The Vegetation of Middle Asia and Southern Kazakhstan*). 2nd ed. Tashkent. 452 pp. + 577 pp. (2 vols., in Russian).

Petrov, M. P. 1966-67. (*The Deserts of Central Asia*). 2 vols. Moskva-Leningrad. 274 pp. + 286 pp. (in Russian).

Popov, M. G. 1940. (*The Plant Cover of Kazakhstan*). Moskva. 216 pp. (in Russian).

Suslov, S. P. 1961. *Physical Geography of Asiatic Russia*. Translated from Russian by N. D. Gershevsky (J. E. Williams, ed.). W. H. Freeman, San Francisco. 594 pp.

Troll, C. (ed.) 1972. *Geoecology of the High-Mountain Regions of Eurasia*. Erdwissenschaftl. Forschung, vol. 4. Franz-Steiner-Verlag, Wiesbaden.

Walter, H. 1968. *Die Vegetation der Erde in öko-physiologischer Betrachtung*. Vol. II: Die gemäßigten und arktischen Zonen. Jena: VEB Gustav-Fischer-Verlag. 1002 pp.

Walter, H. 1973. *Die Vegetation der Erde in öko-physiologischer Betrachtung*. Vol. I: Die Tropischen und subtropischen Zonen. Stuttgart: VEB Gustav-Fischer-Verlag. ??? pp.

Walter, H. 1974. *Die Vegetation Osteuropas, Nord- und Zentralasiens*. "Vegetation der einzelnen Großräume" series, vol. VII. Gustav-Fischer-Verlag, Stuttgart. 452 pp.

Walter, H. 1985. *Vegetation of the Earth and Ecological Systems of the Geobiosphere.* 3rd ed. Spinger-Verlag, New York. 318 pp.

Walter, H., and E. O. Box 1983. Chapters 2-9 (deserts of Eurasia) in: *Temperate Deserts and Semi-Deserts* (N. E. West, editor). Elsevier, Amsterdam.

Wu Zh.-Y. and committee (eds.) 1980. *Zhongguo Zhibei* (Vegetation of China). Science Press, Beijing. 1375 pp + 339 B/W photos (in Chinese, Latin-Chinese species lists; no index).

Yunatov, A. A. 1950. *The Main Features of the Plant Cover of the Mongolian People's Republic.* Publ. Mongol.

Zhao S.-Q. 1986. *Physical Geography of China.* Science Press (Beijing) and John Wiley & Sons (New York). 209 pp + color photographs.

Zohary, M. 1974. *Geobotanical Foundations of the Middle East.* "Geobotanica Selecta" series, vol. III. Gustav-Fischer-Verlag, Stuttgart. 340 pp.

f. Semi-desert and desert vegetation

Elgene O. Box (*Department of Geography, University of Georgia, Athens, Georgia, USA*)

The present-day geologic and physiographic structure of Asia is centered on the Himalayan Mountains and Tibetan Plateau. A mountain node also exists at the western end of the Himalaya, from which other major mountain ranges radiate in various directions. The most important of these is the Tien Shan-Altai system, which extends to the north-northeast into Mongolia, dividing the dry, temperate interior of Asia into:

1) a western part, called Middle Asia in Russian literature (essentially Turkestan and the Turanian Basin), influenced far inland by westerly winds from the Mediterranean; and

2) an eastern part, called Central Asia (essentially the Tibetan plateau and northwestern China, plus Mongolia) dominated by the Asian monsoon system.

This dry region of interior Asia also includes the Asian portion of the temperate grassland corridor that extends from the Ukraine to Mongolia and northern China. These temperate grasslands range from tall meadow-steppes in the north to drier, open steppes in the south, following the north-south moisture gradient which obtains across most of the continent. These steppes eventually grade southward into the temperate semi-deserts and deserts.

The desert region in our study area lies almost entirely in Central Asia, i.e. east of the Tien Shan and Altai barriers. This dry region includes the Tien Shan region of central Xinjiang, Kashgaria and the Tarim Basin (in southwestern Xinjiang), and Gansu and western parts of Inner Mongolia (e.g. Ala-Shan Mountains), as well as Dzungaria, which forms the transition from Middle Asia to Central Asia. Tibet is also dry but is considered separately.

Of course the vegetation of Central Asia is closely related to that of Middle Asia and even of the Middle East. For regional vegetation descriptions, one might consult the following.

General:	Archibold (1995), Walter (1968, 1973, 1974, 1985)
Dry regions:	Breckle (1983), Davis et al. (1971), Freitag (1971), Korovin (1961-62), Petrov (1966-67), Popov (1940), Walter & Box (1983), Yunatov (1950), Zohary (1974)
Mountains:	Chang (1983), Chen et al. (1986), Troll (1972).

Deserts (*sensu strictu*) have essentially no vegetation, while semi-deserts have scattered plants. Desert conditions may have existed since the earlier Paleozoic (e.g. Glennie 1987). Whether the desert flora arose this early, or in the Miocene (expanding during the colder, drier Pliocene and Pleistocene, as suggested by Axelrod 1958), the desert flora of Asia has probably been closely related to that of northern Africa for a long time. Total species richness is low and there are essentially no true native stem-succulents, but the vegetation of the Middle Eastern deserts shows a wide variety of adaptations of form and seasonality to avoid dehydration and maintain active metabolism (cf. Walter 1973, pp. 693, based on Zohary). Some dwarf-shrubs are evergreen but greatly reduce their leaf area at the beginning of the dry season (e.g. *Artemisia monosperma, Reaumuria palestina, Salsola villosa, Suaeda palestina, Zygophyllum dumosum*). Some are wintergreen shrubs, losing their leaves in summer (e.g. *Lycium arabicum, Anagyris foetida*), while some (generally dwarf-shrubs) shed their leaves but retain evergreen stems, as in *Retama* and *Calligonum* species. Some have rather grayish, soft, deciduous leaves but keep smaller leaves during the summer (e.g. *Artemisia herba-alba*). Some are totally leafless, like *Ephedra*. Perhaps most interesting are the leafless shrubs and arborescents with modular stems and green, photosynthetic but disposable bark segments, e.g. *Haloxylon persicum* and *Anabasis articulata*. Where more water is available, there may be scattered trees such as acacias, deciduous thorn-shrubs such as *Noaea*, or desert grasses such as *Aristida*. Many of these desert taxa extend well into Middle and even Central Asia.

The climates of the temperate deserts in Central Asia are warm to hot in the summer and severely cold in the winter. Precipitation is confined almost completely to summer, brought by monsoon storms which manage to penetrate into the continental interior. Soils in all regions are coarse and skeletal, salinized in areas of internal drainage. The Central Asian deserts are totally continental and separated from the subtropical deserts of southwestern Asia, although they may share many genera and some species.

Our fieldwork in the dry region of Central Asia was confined to western China, at the following locations:

- desert vegetation and montane forests of Dzungaria (Xinjiang, June 2005);
- semi-desert vegetation of Kashgaria and the Tarim Basin (Xinjiang, July 2005); and
- montane deciduous and conifer forests of dry-climate Gansu (July 2006);

as well as (from earlier work):

- steppe with pine-forest outliers in eastern Inner Mongolia (July 2000); and
- steppe and dry montane forests in western Inner Mongolia (July 2002).

We were, however, also able to make a brief stop in the Tuva Republic of southwestern Siberia, in the dry steppe/semi-desert area south of the Sayany Mountains near Kyzyl. This area represents another transition between Middle Asia and summer-rain Central Asia.

Local taxonomic assistance was less available in the dry areas, so our data-base consists only of a small number of relevés from Dzungaria and the Tarim Basin (2005), from montane forests of Gansu (2006), and from dry steppe and semi-deserts of Inner Mongolia (2002) and the Tuva area (2007). We do not have enough data to do formal phytosociological analyses, but we could understand the environmental relationships.

Dzungaria extends across northernmost Xinjiang Province of western China, east of the Dzungarian Gate, which represents a gap in the Tien Shan-Altai mountain system. This corridor between Middle Asia and the Gobi, as well as the Gobi itself, represents a region of rockier substrates and deserts dominated by desert shrubs and dwarf-shrubs such as *Anabasis*, *Calligonum* and *Haloxylon persicum*, sometimes with *Stipa* bunch grasses. Smaller, more extremely xeromorphic dwarf-shrubs included *Salsola*, whitish-gray *Astragalus*, *Atraphaxis* (Polygonaceae, with minute oval leaves), and both green and whitish species of *Artemisia*. Isolated trees of *Populus, Tamarix* and occasionally *Haloxylon* may occur along streams. The most widespread green landscapes seemed to be *Calligonum* and *Haloxylon* shrub-steppes, where sandier substrates occurred. On the other hand, enormous areas were dominated by a sandy rubble desert with only sparse herbs and small dwarf-shrubs and semi-shrubs.

Ürümchi, the Xinjiang capital, is at about 900m elevation on the north slope of the Tien Shan. There is essentially no groundwater on the slopes or uplands, so there is essentially no vegetation except small bushes in ravines. In the Turpan Basin to the east (and south of the easternmost Tien Shan) there is almost no vegetation at all over very large areas. One part of this area falls below sea level and represents the hottest part of the Central Asian desert. Even so, the area around Turpan is ingeniously irrigated with mountain runoff water (via underground ducts) and produces food.

In the Tarim Basin to the southwest, the Takla Makan desert is a large sand sea within the horseshoe of mountains (open to the east) formed by the Tien Shan on the north, the Pamirs in the center, and the Karakoram and Kunlun ranges on the south. Together these ranges form one of the most effective rain shadows in the world, and precipitation is very rarely recorded in the Tarim Basin. Rubble desert appears at the western end of the Tarim Basin, near the dry mountains, with *Salsola*, *Calligonum*, and occasional patches of *Halocnemon*. Despite the dry appearance, however, runoff from the mountains (on all sides) does generate intermittent and permanent streams that extend into the Tarim Basin. Along these streams one can find riparian strips of the phreatophytic *Tamarix ramosissima* as well as the widespread *Populus diversifolia*, *P. euphratica*, and *Ulmus pumila*. In some areas there are even extensive marshes of *Phragmites, Typha*, and *Scirpus* species. There is little vegetation on the areas of mobile sand, but extensive efforts are underway to stabilize the sands with plantations of native desert shrubs, especially *Haloxylon persicum, H. ammodendron*, and *Calligonum*. In natural stands, these large shrubs grow continually upward, above the rising surface of mobile sand, until it then shifts again and the shrubs are left on top of pedestals called nebkhas.

One characteristic of the sandy deserts is the dominance of both typically small and much larger xeromorphic shrubs, some of them leafless and some at least partly evergreen. Reaching 2 m in height, leafless *Haloxylon persicum* extends over the whole region and even over into the Gobi desert. In the deep-sand Kara-Kum desert of Middle Asia, *H. ammodendron* can become a leafless tree reaching 8m in height. This is the only cold-winter desert region in the world in which a tree form gains even local dominance. Other important desert shrubs, especially in Middle Asia, include *Artemisia pauciflora*, *A. terrae-albae, Halostachys caspica, Anabasis salsa, Halocnemum strobilaceum*, and *Kochia prostrata*, along with steppe and desert grasses such as *Festuca sulcata, Stipa capillata, Koeleria cristata*, and *Agropyron repens*. In areas of flat terrain and finer soil, mini-geophytes such as *Poa bulbosa* form vernal carpets of miniature flowers (see Walter 1974, p. 254).

The Tibetan Plateau (average elevation around 4000 m) is a region of dry steppes, alpine mats (especially of *Kobresia* species), dwarf conifer scrub of *Juniperus* and *Sabinia*, and other sparse, low-growing, often cushion-shrub vegetation adapted to harsh conditions. Many familiar genera from Central Asia (and Middle Asia) are represented, including *Caragana, Reaumuria, Acantholimon, Astragalus, Tanacetum, Artemisia, Ptilagrostis*, and *Festuca*. Some species even reach the higher elevations, including *Eurotia ceratoides* and *Kochia prostrata*. East Asian elements are important only in the east but include *Gentiana, Primula, Saxifraga, Saussurea*, and *Rhododendron*, among others. Holarctic elements are few, but some are very abundant, especially in the alpine mats and marshes: *Kobresia, Carex, Heleocharis, Eriophorum*, and *Juncus*. Where moisture permits, subalpine tall-forb stands (as in the Russian Far East) include such genera as *Aconitum, Delphinium, Ligularia, Polygonum* and *Rheum*. These different geoelements all represent taxa that migrated into Tibet after the last Pleistocene glaciations. The vegetation of Tibet is especially well summarized by Chang (1983; see also Chen et al. 1986, Troll 1972, Walter 1974, Wu 1980).

Pine forests cover extensive lowland areas in Asia but also occur in mountains of dry regions, especially after soil erosion following cutting. In southwestern China, forests of *P. armandii* occur in Sichuan and on the Yunnan plateau. In addition to pine, "Chinese fir" (*Cunninghamia lanceolata*) is important in secondary landscapes and is widely planted. In the Tien Shan and Altai systems, the montane conifer forests are simpler, dominated often by *Picea schrenkiana* (as in Middle Asian mountains). We found such a forest of *P. schrenkiana* at 1800m in the Tien Shan above Ürümchi, growing on a dry slope where one would never have thought spruce possible. In more moist situations, though, montane and subalpine forests may include shade-tolerant *Pinus sibirica*, as well as boreal *Picea* and *Abies*, larches, and *Pinus sylvestris* (see Walter 1974; cf. Walter & Box 1983: chapter 7). In the Altai Mountains of northernmost Xinjiang, near the Kazakh and Mongolian borders, we found extensive montane forests (1500-1800m) of *Picea obovata* with *Larix sibirica* and occasional *Abies sibirica*.

Wetlands in dry regions include marshes and inland deltas, but also swamps, bogs, and (*sensu lato*) even lakes and streams. Most wetlands are highly productive systems when not badly degraded, have important economic and social benefits for local human populations, and perform useful ecological services such as cleansing wastewater. Wetlands also support a wide range of animal life, often far beyond their own borders. Most important in drier climates are probably the freshwater marshes which are critical for birds migrating between wintering areas in tropical Asia and summer breeding grounds in Siberia. Such marshes may occur in depressions as well as along streams, especially in the deserts of western China, the grasslands of northern China and Mongolia, and in Middle Asia and the highlands of Tibet. These marshes are composed primarily of reeds (*Phragmites*), cattails (*Typha*), sedges (*Cyperus, Scirpus, Carex*) and similar herbaceous plants. If seasonal pools form, small marshes of sedges and reeds occur. Halophytes include species such as *Halocnemum strobilaceum* on very saline sites and *Nitraria retusa* in brackish water. Deciduous but otherwise juniper-like tamarisk trees (*Tamarix* spp.) also occur where groundwater can be reached, generally at greater depth.

References

Archibold, O. W. 1995. *Ecology of World Vegetation*. Chapman and Hall, London. 510 pp.

Axelrod, D. I. 1958. Evolution of the Madro-Tertiary flora. *Botanical Review*, 24:433-509.

Box, E. O. 1995. Global and local climatic relations of the forests of East and Southeast Asia. In: *Vegetation Science in Forestry* (E. O. Box et al., eds.), pp. 23-55. Dordrecht.

Box, E. O. (ed.), with R. K. Peet, T. Masuzawa, I. Yamada, K. Fujiwara and P. F. Maycock (co-eds.) 1995. *Vegetation Science in Forestry: Global Perspective based on Forest Ecosystems of East and Southeast Asia*. Kluwer, Dordrecht. 663 pp.

Breckle, S. W. 1983. Temperate Deserts and Semi-Deserts of Afghanistan and Iran. In: *Temperate Deserts and Semi-Deserts* (N. West, ed.), pp. 271-319. Elsevier, Amsterdam.

Chang D. H. S. 1983. The Tibetan Plateau in relation to the vegetation of China. *Ann. Missouri Bot. Gard.*, 70:564-570.

Chen L.-Zhi, Chang Hs.-Sh., and Committee 1986. *Proceedings of the International Symposium on Mountain Vegetation*. Beijing: Botanical Society of China. 297 pp.

China Natural Geography Editorial Committee (eds.) 1984. (*China Natural Geography: Climate.*) Academia Sinica. Science Press, Beijing. 161 pp. (in Chinese).

Davis, P. H., P. C. Harper, and I. C. Hedge 1971. *Plant Life of South-West Asia.* Botanical Society of Edinburgh. 335 pp.

Freitag, H. 1971. Die natürliche Vegetation Afghanistans. *Vegetatio*, 22:285-344.

Glennie, K. W. 1987. Desert sedimentary environments, present and past – a summary. *Sedimentary Geology*, 50:135-165.

Korovin, E. P. 1961-62. (*The Vegetation of Middle Asia and Southern Kazakhstan*). 2nd ed. Tashkent. 452 pp. + 577 pp. (2 vols., in Russian).

Petrov, M. P. 1966-67. (*The Deserts of Central Asia*). 2 vols. Moskva-Leningrad. 274 pp. + 286 pp. (in Russian).

Popov, M. G. 1940. (*The Plant Cover of Kazakhstan*). Moskva. 216 pp. (in Russian).

Suslov, S. P. 1961. *Physical Geography of Asiatic Russia.* Translated from Russian by N. D. Gershevsky (J. E. Williams, ed.). W. H. Freeman, San Francisco. 594 pp.

Troll, C. (ed.) 1972. *Geoecology of the High-Mountain Regions of Eurasia.* Erdwissenschaftl. Forschung, vol. 4. Franz-Steiner-Verlag, Wiesbaden.

Walter, H. 1968. *Die Vegetation der Erde in öko-physiologischer Betrachtung.* Vol. II: Die gemäβigten und arktischen Zonen. Jena: VEB Gustav-Fischer-Verlag. 1002 pp.

Walter, H. 1973. *Die Vegetation der Erde in öko-physiologischer Betrachtung.* Vol. I: Die Tropischen und subtropischen Zonen. Stuttgart: VEB Gustav-Fischer-Verlag. ??? pp.

Walter, H. 1974. *Die Vegetation Osteuropas, Nord- und Zentralasiens.* "Vegetation der einzelnen Großräume" series, vol. VII. Gustav-Fischer-Verlag, Stuttgart. 452 pp.

Walter, H. 1985. *Vegetation of the Earth and Ecological Systems of the Geobiosphere.* 3rd ed. Spinger-Verlag, New York. 318 pp.

Walter, H., and E. O. Box 1983. Chapters 2-9 (deserts of Eurasia) in: *Temperate Deserts and Semi-Deserts* (N. E. West, editor). Elsevier, Amsterdam.

Wu Zh.-Y. and committee (eds.) 1980. *Zhongguo Zhibei* (Vegetation of China). Science Press, Beijing. 1375 pp + 339 B/W photos (in Chinese, Latin-Chinese species lists; no index).

Yunatov, A. A. 1950. *The Main Features of the Plant Cover of the Mongolian People's Republic.* Publ. Mongol.

Zhao S.-Q. 1986. *Physical Geography of China.* Science Press (Beijing) and John Wiley & Sons (New York). 209 pp + color photographs.

Zohary, M. 1974. *Geobotanical Foundations of the Middle East.* "Geobotanica Selecta" series, vol. III. Gustav-Fischer-Verlag, Stuttgart. 340 pp.

B. Notes on Vegetation of the Western Sayan Mountains, Russia

Ken Sato (*Hokkai-Gakuen University, Sapporo, Japan*)

Field survey members (All botanists written below)
Russian botanists: Pavel Krestov (PK), Valentine Yakubov (VY), Dina Nazimova (DN), Olga Drobushevskaya (OD), Dilshad Ismailova (DI), Baboy Semion (BS), Nikolai Stepanov (NS)
American botanist: Elgene O. Box (EB)
Japanese botanists: Kazue Fujiwara (KF), Yukito Nakamura (YN), Ken Sato (KS), Takuma Nakamura (TN)

Abstract

In the summer of 2007, the vegetation of Ergaki National Park in the western Sayan Mountains (Russia) was surveyed by the phytosociological method. The altitudinal distribution of vegetation in the Western Sayan Mountains is as follows: 1) Sub-boreal belt characterized by Scots pine (*Pinus sylvestris*) forest (below 450 meters); 2) Dark taiga belt composed mainly of Siberian five-needled pine (*Pinus sibirica*) (450-800 meters); 3) Dark taiga belt consisting mainly of Siberian pine, Siberian spruce (*Picea sibirica*) and Siberian fir (*Abies sibirica*) (800-1500 meters); and 4) Alpine belt (above about 1500 meters). Our survey concentrated on belts 1, 3 and 4.

In the alpine belt we recognized six plant communities, as shown in tables. On the rather gentle ridges above about 1500 meters, there are many scattered outcrops, on which the *Paraquilegia microphylla* community occurs (Comm. 1.1). Several kinds of patterned ground, such as polygons, solifluction terraces, and solifluction lobes, were developed on the gentle ridges where snow is blown away in winter. A wind-blown herbaceous community (Comm. 1.2: the *Festuca sphagnicola-Campanula dasyantha* community) occupies the barren parts of polygons and solifluction terraces. Elsewhere, dwarf-shrub communities (Comm. 1.3) form a dense plant cover at polygon margins and at the front of solifluction terraces. Of the two dwarf-shrub communities, the *Dryas oxyodonta* community occurs on sites with less snow cover than the sites of the *Arctous erythrocarpa-Vaccinium uliginosum* community. Snow-patch communities (Comm. 1.4) can be seen on the leeward depressions and in the cirques, but do not cover large areas. The *Sibbaldia procumbens* community is common on snow patches of leeward depressions, and the *Dolonicum altaicum* community was seen in the cirque of Silks Lake.

Near the forest limit at about 1500 meters, we recognized three plant communities: a tall forb community (Comm. 2.1), thickets dominated by *Betula nana* ssp. *rotundifolia* (Comm. 2.2), and thickets of *Alnus fruticosa* (Comm. 2.3). These plant communities occur at the ecotone between tree limit and forest limit, so we call these communities "higher subalpine vegetation". The tall forb community (Comm. 2.1) occurs on avalanche slopes near the forest limit and also develops as a substitute meadow after cutting of the dark taiga at lower altitudes. Among the *Betula nana* ssp. *rotundifolia* thickets (Comm. 2.2), the thicket with dwarf shrubs can be thought of as an ecotone community between Comm. 1.3 and Comm. 3.1; and the thicket with tall forbs can be interpreted as an ecotone community between Comm. 2.1 and the above community. The *Betula nana* ssp. *rotundifolia*-dominated thicket occupies, physiognomically, a rather broader area around the forest limit but includes two floristic types due to different habitats. The *Alnus fruticosa* thicket occurs on steeper, especially north-facing slopes. This occurrence is similar to that of *A. viridis* in the European Alps and of *A. maximowicii* in the Far East.

The dark-taiga belt (800-1500 meters) is characterized by the occurrence of *Pinus sibirica-Abies sibirica* forest (Comm. 3.1), which includes three stand groups: the *Vaccinium myrtilus* group (typical type), the *Athyrium distentifolium* group (unusual type), and the *Calamagrostis obtusata* group (lower-altitude type). Larch forest (Comm. 3.3, the *Larix sibirica* forest) can be seen on the southern slope of the mountain, where the climate is more continental.

In the sub-boreal belt (below 450 meters), the *Pinus sylvestris-Betula pendula* forest (Comm. 3.2A) and the *Betula pendula* forest (Comm. 3.2B) were recognized. The former Scots pine forest has been influenced by fire to various degrees, and the latter has changed from the former due to fire.

Basic data on vegetation of West Sayan Mountains

1 Alpine vegetation

1.1 Rock crevice herbaceous community: the *Paraquilegia microphylla* community (Table 1 & Table 14-1)

1.2 Wind-blown herbaceous community: the *Festuca sphagnicola-Campanula dasyantha* community (Table 2 & Table 14-2)

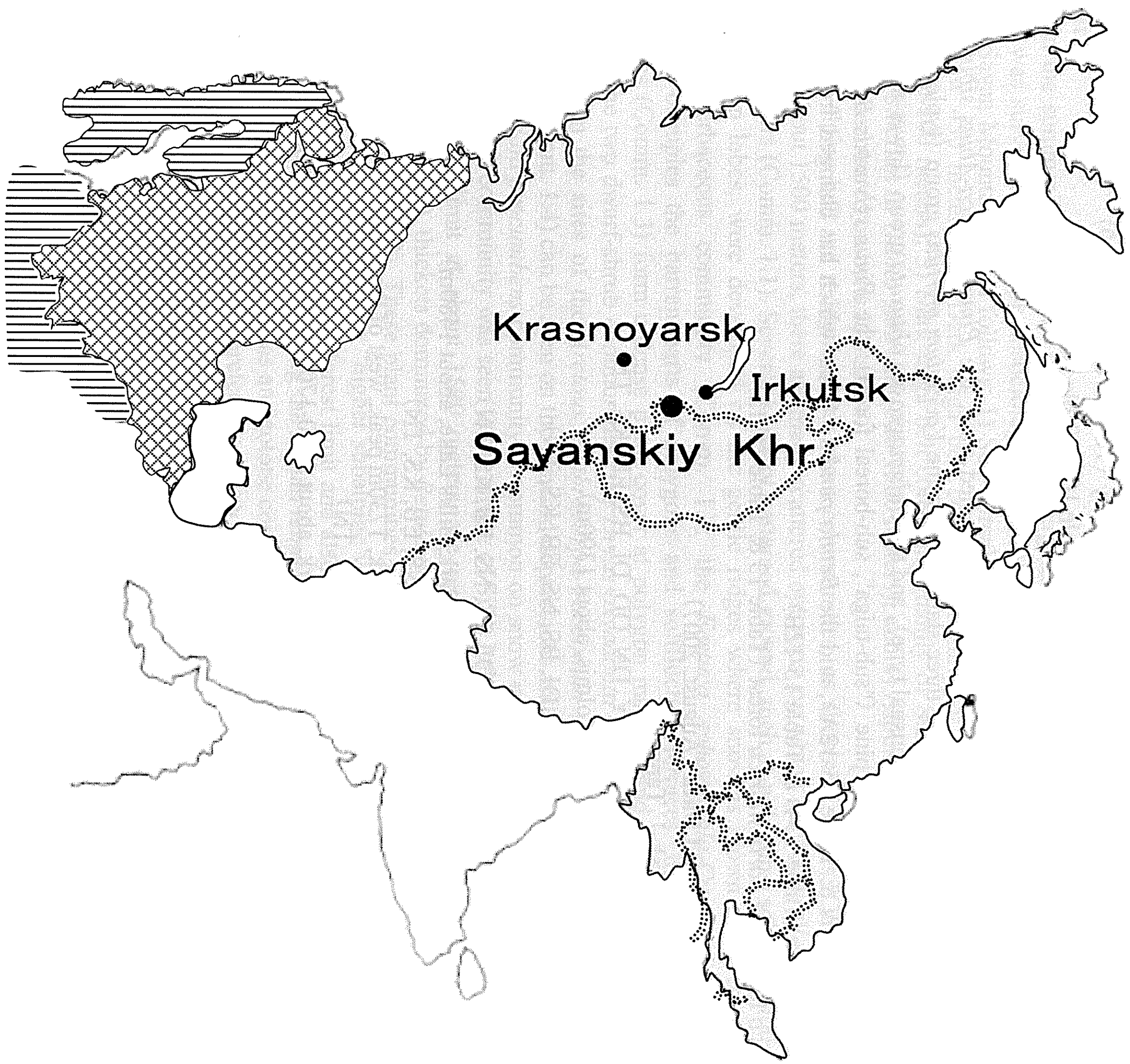
1.3 Wind-blown dwarf-shrub communities: the *Dryas oxyodonta* community (Table 3 & Table 14-3) and the *Arctous erythrocarpa-Vaccinium uliginosum* community (Table 4 & Table 14-4)
1.4 Snow-patch herbaceous communities: the *Sibbaldia procumbens* community (Table 5 & Table 14-5) and the *Dolonicum altaicum* community (Table 6 & Table 14-6)

2 Higher subalpine vegetation at the ecotone between tree limit and forest limit
2.1 Tall forb community (Table 7 & Table 14-7)
2.2 The *Betula nana* ssp. *rotundifolia*-dominated thickets as ecotone communities: the *Betula nana* ssp. *rotundifolia* thicket with dwarf shrubs as an ecotone community between Comm. 1.3 and Comm. 3.1 (Table 8 & Table 14-8); and the *Betula nana* ssp. *rotundifolia* thicket with tall forbs as an ecotone community between Comm. 2.1 and the above community (Table 9 & Table 14-9).
2.3 The *Alnus fruticosa* thicket on steeper slopes (Table 10 & Table 14-10).

3 Boreal and sub-boreal forests
3.1 Dark taiga composed of spruce, fir and five-needled pine: the *Pinus sibirica-Abies sibirica* forest (Table 11 & Table 15-11), including three stand groups: the *Vaccinium myrtilus* group (typical type), the *Athyrium distentifolium* group (unusual type), and the *Calamagrostis obtusata* group (lower-altitude type)
3.2 More open forest of Scots pine ("sub-taiga", sub-boreal forest): the *Pinus sylvestris-Betula pendula* forest (Table 12-A & Table 15-12A), and the *Betula pendula* forest which has changed from the above forest due to fire (Table 12-B & Table 15-12B).
3.3 Larch forest: the *Larix sibirica* forest (Table 13 & Table 15-13)

Appendix: Schedule and Data (August, 2007)

Aug. 1: (Krasnoyarsk-) Tanzybey
  Releves (Quadrats) 1-3 (PK, VY, DN, OD, DI, BS, EB, KS, TN)
Aug. 2: around Tanzybey (Mt. Kolmis, about 1390m)
  Releves 4-9 (PK, VY, DN, OD, DI, BS, NS, EB, KS, TN)
Aug. 3: around Tanzybey
  Releves 10-13 (PK, VY, DN, OD, DI, BS, NS, EB, KS, TN)
Aug. 4: Sayan Mountains (Ergaki National Park, Silks Lake, about 1480m)
  Releves 14-23 (PK, VY, DN, OD, DI, BS, NS, EB, KS, TN)
Aug. 5: Sayan Mountains (Ergaki National Park, 1730m peak, west of the pass)
  Releves 24-37 (PK, VY, OD, DI, BS, NS, KS, TN)
Aug. 6: Sayan Mountains (Ergaki National Park, about 1500-1700m, east of the pass)
  Releves 38-55 (PK, OD, DI, BS, NS, KS, TN)
Aug. 7: Southern slope of Sayan Mountains
  Releves 56-57 (PK, VY, DN, OD, DI, BS, NS, EB, KS, TN)
Aug. 11: Sayan Mountains (Mt. Tushkanchik, Ergaki National Park)
  Releves 91-112 (KF, YN, PK, VY, DN, OD, DI, BS, NS, KS, TN)


Krasnoyarsk
Irkutsk
Sayanskiy Khr.

C. Map of Asian Vegetation: Legend Items and Text Description

Elgene O. Box (*Department of Geography, University of Georgia, Athens, Georgia, USA*)
Kazue Fujiwara (*Graduate School of Environment and Information Sciences, Yokohama National University, Yokohama, Japan*)

The initial draft of a legend was based on the global, pheno-physiognomic vegetation classification system developed at Tokyo University for mapping both potential and actual vegetation at global scale (Box 1995; see also Box & Fujiwara 2005). That classification, with 50 basic vegetation types, was designed to be useable for both climate-based and satellite-based global vegetation mapping, due to its strict definition of vegetation types by pheno-physiognomy (i.e. physical structure and its seasonal variations). That set of types was first adapted for the Asian vegetation map at a team meeting at Chiba University in January 2005. It was updated and improved each year thereafter at other Chiba meetings. The final version before actual mapping (from January 2007) was used to guide development of the first map drafts, keeping the pheno-physiognomic basis as far as possible while adding other land-cover types, such as cropland. Much discussion centered on considerations of scale, dynamics, and vegetation mosaics.

The map included in this report was produced from satellite data and thus represents actual vegetation. In the end, of course, it was not possible to show all the vegetation types known from fieldwork or the literature, due sometimes to their small areas and at other times to lack of training sites to guide the satellite recognition algorithm. Some original vegetation types were once very extensive but have been greatly reduced, appearing now only as very small, widely scattered areas on the map, even though they may still represent the potential natural vegetation over large areas. Many legend items were based on zonal vegetation types, i.e. physiognomically fairly uniform types of potential natural vegetation of the major bioclimatic zones. The text below treats the vegetation classes as they appear (by name) in the map legend, with the colors involved.

1. **Evergreen Broad-Leaved Forests** (darkest green)

These forests are tall and dense, constituted by trees bearing simple laurophylls, i.e. dark green but somewhat glossy, evergreen leaves like those typical of the laurel family. Their dark color is due to their high chlorophyll content, as needed for photosynthesis in the dark forest understorey, where even tall trees spend part of the lifetimes. The trees generally have deep root systems (except where groundwater is high, as in tropical rainforest) and do not suffer from drought at any time during the year. In the perhumid tropics near the equator, there is essentially no seasonality. This means that the vegetation is not only evergreen but actually evergrowing, i.e. flowering, fruiting, foliation, defoliation, etc. may all be occurring simultaneously, even on different branches of the same tree. Productivity levels are high, and the tropical laurophyll forests are considered the most diverse, species-rich forests on the planet.

Evergreen broad-leaved forests include tropical rainforests, subtropical to warm-temperate "laurel" (laurophyll) forests, and tropical montane forests involving taxa similar to both. Tropical rainforest is the potential natural vegetation of the humid tropical zone. Laurel forests represent subtropical and warm-temperate analogs of the tropical rainforest and constitute the potential natural vegetation of larger parts of East Asia, where winter temperatures never fall below about -15°C (warm-temperate) or -2°C (subtropical). The laurel forests that once covered most of southern China and the southern half of Japan have been decimated almost completely in the lowlands and remain only as small remnants around shrines and temples. Many of the main tree species do remain in the landscape and provide seed sources for possible forest recovery. Some forested areas remain in mountainous terrain but are difficult to show at the scale of our map.

- Tropical Rainforest	Within our study area, lowland tropical rainforest is indicated only in the lower Malay peninsula and along the coast of Cambodia, but it also is indicated prominently in windward Kerala.
- Tropical Montane Forest	Montane laurophyll forest is suggested on the map over somewhat larger parts of Southeast Asia, especially in the mountains of Vietnam, northern Myanmar, peninsular Thailand, and in the Philippines (especially Mindanao).
- Evergreen Broad-Leaved Forest	Although small areas of laurel do remain in some areas (mainly in mountains), none are really shown on the map.

Deciduous Broad-Leaved Forests and Woodlands

Deciduous broad-leaved forests vary more widely in stature and canopy closure, from tall, closed forests to shorter, somewhat open woodlands, in which the tree crowns may barely overlap or touch at all. The deciduous leaves are lighter green, thin, and soft, with high potential rates of $CO2$ intake and oxygen release; indeed these malacophylls (soft leaves) are "throw-away" leaves, designed for maximum photosynthetic rates during the favorable season but then discarded during the unfavorable dry or cold season.

Deciduous broad-leaved forests and woodlands fall into two broad categories, those that defoliate due to an extreme dry season (raingreen) and those that defoliate due to a cold winter (summergreen). Closed deciduous forests of both types have high productivity levels and can be quite species-rich forests.

2. **Summergreen Broad-Leaved Forests and Woodlands** (lightest green)

Summergreen broad-leaved forests are the potential natural vegetation of the humid, four-season, typical temperate zones of the world, including East Asia, eastern North America, and much of Europe. In Asia this area includes the northern half of Japan, most of Korea, parts of the Russian Far East, most of Manchuria, and parts of northeastern and eastern China. The most common trees are from genera such as *Fagus, Quercus, Acer, Tilia*, and *Fraxinus*. Summergreen forests also constitute the main secondary forest stage within the warm-temperate portion of the potential zone of evergreen broad-leaved forests. This means that deciduous broad-leaved forests can be quite extensive in East Asia, and they are familiar, seasonally colorful parts of temperate landscapes.

In addition, summergreen forests composed of species tolerating a shorter summer growing season are important in the sub-boreal zone and even in truly boreal latitudes in maritime areas. Important short-season tree include *Betula pendula, B. platyphylla* and other birches, and *Populus tremula,P. davidiana a*nd other poplars. Individual tree species themselves occur even further north, as secondary stages or admixtures in boreal forests. In between, the zonal transitional forest type is a cool-temperate mixed forest involving, in particular *Fraxinus, Acer, Tilia*, etc., plus *Pinus koreana* and perhaps other non-boreal conifers; this mixed forest zone is also well developed in northeastern North America, with *Pinus strobus*. These mixed forests also include the montane belts of humid temperate mountains, with *Pinus* and boreal conifers

Typical summergreen broad-leaved forests, as a class, are also one of the most resilient of the world's main biome types, being able to regenerate within a century or less to a stature approaching that of original forests (albeit with some, usually permanent loss of understorey species). As a result, summergreen forests (including mixed forests) should cover relatively large areas on the map.

- Summergreen BL Forest — On the map, summergreen forest is indicated over much of Dahuria, Primorye, Manchuria, and Korea, as well as northern Japan and small areas in Southeast Asia; it is also suggested as part of the landscape across the broad sub-boreal zone of southern Siberia, eastward into European Russia, plus part of southern Kamchatka.

- Temperate Mixed Forest — Some of summergreen forest indicated, perhaps especially in Korea, may have significant amounts of *Pinus koreana* and in fact be mixed forest.

- Sub-Boreal and Boreal Birch/Aspen Forests — This would be the type of summergreen forest, or sometime more open woodland, indicated across the sub-boreal (sub-taiga) zone of Russia, as well as in maritime areas like Kamchatka.

- Non-boreal Poplar Forests — These are mainly riparian forests, composed of *Populus*, *Chosenia* and *Salix* species; such forests occur only in small, linear areas that do not show on the map but could be found frequently along the wide rivers of Siberia.

3. **Raingreen Forests and Woodlands** (bluish green)

Raingreen forests (always broad-leaved) are the potential natural vegetation of tropical and some subtropical areas that have strongly contrasting wet and dry seasons, including much of Africa and South America. In more humid areas most raingreen trees have typically light-green malacophylls (soft leaves), but in drier areas many species can have surprisingly hard (for deciduous), darker-green leaves. Because many raingreen trees are fast growing, they may also be common colonizers after forest destruction (e.g. *Macaranga* species) and may constitute secondary forest stages in the humid tropical zone.

Across interior tropical Asia, taller, more luxurious raingreen forests in Southeast Asia (e.g. Myanmar, Thailand, Laos) grade westward into somewhat shorter raingreen forests and woodlands (e.g. Dry Deciduous Forest) in India – but this pattern is also confounded frequently by orographic and other topographic effects (e.g. the Dry Belt of Burma). Especially important in these forests are trees from the family Dipterocarpaceae, such as *Shorea*, (as also in the evergreen forests of tropical Asia). In Asia, raingreen woods may also replace potentially semi-evergreen forest after fire and may occur on areas of shallow soil. In such cases the leaves are generally large and fairly hard, as in India and much of interior Southeast Asia.

Our study area did not include large parts of tropical Asia, so raingreen forests and woodlands appear only in smaller areas on the map, only in Southeast Asia.

- Raingreen Forests and Woodlands — These are indicated on the map almost only in Southeast Asia, for example in southern Laos and Vietnam, in central Thailand, and around the northern periphery of the Burmese dry belt; interestingly, very little is indicated over most of India (suggesting greater land degradation).

4. Evergreen Needle-Leaved Forests and Woods (rich green)

Needle-leaved forests are constituted by coniferous trees bearing needle-like leaves that may be round (e.g. pines) or flattened (e.g. fir) in cross-section. Most conifers are also evergreen, with needles that are typically dark green (high chlorophyll content, for shade tolerance) except in drier areas, where canopy closure is less and sunlight is more available. Conifers typically have shallow, spreading root systems, which would make them potentially vulnerable to drought. On the other hand, the needles are typically coriaceous, sometimes even harder (sclerophyllous), and resist water loss better than do most broad-leaved trees of humid climates, especially deciduous trees.

Evergreen needle-leaved forests composed of a few species of spruce (*Picea*), pine (*Pinus*) and sometimes fir (*Abies*) are the potential natural vegetation of the broad boreal zone across the high-latitude continental areas of the Northern Hemisphere. In Eurasia, such Boreal Forests (cf taiga) extend from Scandinavia to central Siberia and are largely composed of *Picea obovata*, *Pinus sylvestris,* and *Pinus sibirica*, with admixtures of *Larix* (larch: deciduous). In central and eastern Siberia they are gradually replaced eastward by larch woods, where winter is too cold for the evergreens, but the evergreen conifer forests reappear in the more maritime Russian Far East. Evergreen needle-leaved forests also constitute the main type of montane and subalpine vegetation in the temperate and sub-boreal latitudes, except where the climate is too dry during the growing season. Boreal evergreen conifer forests thus cover large areas on the map.

In addition to the boreal conifer forest, pine (*Pinus*) forests are important as secondary woods in temperate, warm-temperate, and even subtropical parts of Asia. Much of the southern half of Japan and of southern China, for example, was converted from the zonal evergreen broad-leaved forest into pine stands through repeated burning and other land-utilization practices. Pine forests maintain themselves further through their resistance to ground fires. The main species are *Pinus densiflora, P. sylvestris*, and *P. tabulaeformis* (temperate and warm-temperate); and *Pinus massoniana* and *Pinus kesiya* (subtropical).

Finally, large areas in interior Japan and other mountainous parts of East Asia are covered by conifer plantations. These "forests" generally involve desirable, straight-growing conifers such as *Cryptomeria* and *Chamaecyparis* or fast-growing pines and *Cunninghamia.*

- Boreal and Subalpine Conifer Forests — The evergreen boreal conifer forest is indicated across much of high-latitude Eurasia (more toward the west) as well as on Sakhalin and in smaller areas near the Amur delta and on the west side of Kamchatka; subalpine conifer forest is conspicuously shown in the southern Ural and the Altai-Sayan mountain areas.

- Open Boreal Taiga — This open, often grassy boreal woodland cannot be separated from more closed forest but does occur widely throughout the boreal zone, often as part of complex mosaics.

- Lowland/Montane Pine Forests — Some of the areas indicated in the sub-boreal zone (e.g. around Lake Baykal) are in fact forests of *Pinus sylvestris.*

- Secondary Pine Forests (temperate/subtropical) — Pine forests within the zones of temperate to subtropical broad-leaved forests are indicated over much of southern China, Japan, and Korea.

- Conifer Plantations — These cannot really be distinguished on the map from other non-boreal conifer forests but do occupy large areas, for example, in the mountains of Japan.

5. Deciduous Needle-Leaved Forests and Woods (bright orange)

Needle-leaved deciduous forests are boreal, summergreen, and composed of only one main tree genus, larch (*Larix*), though sometimes with admixtures of evergreen conifers where winter is less severe. Summergreen larch forests and, more commonly larch woodlands or woodland-scrub mosaics, constitute the potential natural vegetation of the ultra-continental region of central and eastern Siberia, where mean January temperatures may be below -30°C (absolute minimum: -71°C at Oymyakon, in Yakutia) but where summer, though short, can be very pleasantly warm. Larch woods also constitute the northern treeline across much of Siberia, reaching 72° N latitude on the Taymyr Peninsula. Larch woods show no successional pattern but rather involve trees of all ages. Interspersed in the larch mosaics are often thickets of scrubby birch (*Betula*), alder (*Alnus*) or willow (*Salix*), typically no more than 4-6 meters high.

Larch woods range from closed forests to open woodlands. Closed forest is composed of larch (*Larix*) with or without admixtures of *Picea* or other, evergreen conifers, such as *Pinus sibirica.* Open larch taiga is more common and very extensive, also with or without admixtures of other tall conifers but often with an understorey of *Pinus pumila* thickets. Locally (as in the Da Xinggan Ling mountains of Manchuria), there may also be plantation "forests" of larch, usually with no other tree species involved at all

Because of the low sun angle in winter, with no sun at all above the polar circle, it is difficult to get reliable satellite data during the winter months. As a result, much of the boreal zone looks "deciduous" because the satellite cannot see the green foliage of the evergreen conifers. Alternatively, some treatments of the satellite data over-correct for this, showing almost no larch woods. This problem has been partly solved here by using temperature and other criteria as ancillary data.

- Boreal Larch Forests — These are not distinguished on the map from more open larch taiga; closed forest would be most likely to occur in more humid areas such as some mountains.

- Open Larch Taiga — This is mainly what is indicated on the map, over large parts of central and eastern Siberia; in reality, though, it should extend further north almost to the Arctic coast across most of Siberia.

6. Scrub (light olive green)

Scrub is woody vegetation that is not clearly dominated by trees, shrubs, or any particular growth form. It is often a mixture of woody forms and often appears somewhat stunted. Scrub can thus be of many different shapes, sizes, and seasonal patterns, and it is impossible to show the different types on a map with a full range of other vegetation types (since the eye can distinguish at most only about 15-20 different colors).

A few types of scrub vegetation worldwide are: tropical evergreen broad-leaved scrub in peinotrophic areas (e.g. the stunted, sclerophyll *kerangas* on shallow soil in Malaysia and Indonesia; somewhat similar broad-sclerophyll scrub called *cerrado* in Brazil (and similar in parts of India); raingreen thorn scrub throughout the tropical summer-rain zone, both as a natural vegetation type in drier areas and as a degradation form of forest; sclerophyllous *maquis* in regions with Mediterranean-type climate (dry summer); diverse semi-desert scrub in arid regions with higher humidity (coastal) or two rain seasons (e.g. Sonoran Desert); and the wind-stunted krummholz (conifer and broad-leaved) that one finds near treeline in mountains or even along windy coastlines.

At the scale of our map, the only scrub types that appear seem to be the following:

- Scrub in Evergreen-Broadleaf region	This includes substitute shrubs and arborescents on badly degraded substrates in the evergreen broad-leaved zone, especially in China
- Secondary Summergreen woods	Summergreen woods are the zonal secondary forest type in the warm-temperate (but not subtropical) portion of the evergreen broad-leaved forest zone; this is probably what is indicated in the fairly long band stretching from northeast to southwest across China; *Sophora* is very common in degraded areas.
- Subpolar Conifer Krummholz	This would be mainly *Pinus pumila* scrub, as does occur in the mountainous terrain of eastern Siberia; on this map, though, this conifer scrub probably gets included in the larch woods or perhaps even in shrubby tundra.

7. Grasslands and Meadows (yellow)

Grasslands are landscapes on which the vegetation is overwhelmingly composed of grasses, plus an admixture of forbs (herbs that are not grasses or ferns). Meadows are similar except that the forb component is greater, sometimes as much as or more than the grasses. As an ecological plant type, grasses are especially well adapted to drier and other highly variable environments: when it becomes dry (or too cold), grasses simply become dormant, permitting their above-ground biomass to wilt and die (thus reducing water-losing surface area); when water (or warmth) is again available, grasses regenerate quickly from their underground storage organs. In more humid areas, grasses tend to spread by stolons and form dense swards, while in drier areas the grasses grow more in bunch form and may not cover the ground completely. In the Southern Hemisphere most temperate grasslands involve tussock grasses (large clumps sometimes 2m high) and have a quite different appearance from those of Eurasia. Polar grasslands can be extensive but are included here under tundra.

Grasslands, once established, maintain themselves well through their tolerance of fire (which kills most woody plants), grazing, and in some cases through the density of the grass sward itself, which is very difficult for woody plants to invade. Grasslands thus cover very large areas of the globe, including areas of natural grassland and areas where former forest has been removed.

In the tropics, most grasslands are in fact savannas, i.e. grasslands with scattered trees. These are especially prominent over large areas in Africa but not so much in Asia. In mountains, however, large areas of former forest have been converted, perhaps permanently, to montane grasslands with few trees (except in ravines). Such montane grasslands, with genera such as *Imperata*, probably contribute to the speckled pattern seen on the map in Southeast Asia

The most "typical" pure grasslands are in the temperate continental interiors. Natural temperate grasslands occur in these areas when the spring-early summer growing season (rainfall peak) is too short for most typical temperate (summergreen broad-leaved) trees, which need four months for their fruit to ripen. The rest of the year is dry. In interior Eurasia, temperate grasslands cover large areas. Two main types of temperate grassland are typical:

- Tall grasslands (cf. prairie), as occur in areas with more moisture and a longer growing season; in Eurasia this means in a narrow band on the north side of the grassland strip, since the moisture gradient is from better water balance in the north to progressively drier conditions southward. This includes the especially forb-rich Meadow-Steppe, which represents the transition from nemoral or sub-boreal forest to grassland.

- Shorter, often somewhat open grasslands where there is less moisture and the growing season is shorter (called 'steppe' as an English technical term, not to be confused with the Russian 'steppe' meaning grassland in general); these shorter grasslands cover much larger areas, including much of the Mongolian steppe.

These cannot be separated on the map, but temperate grassland in one form or another is indicated across the subhumid mid-latitude interior of Eurasia, especially in an east-west band from the Ukrainian steppes north of the Black Sea to the "elm grasslands" of northern China. Some of this grassland is pasture, as in sub-boreal southeastern and parts of boreal eastern Siberia. The indication of grassland along the Dzhungdzhur coast of the Sea of Okhotsk seems erroneous, however, since steep mountains come very close to this coastline.

True meadows occur mainly as small areas, in mountainous or other complex terrain. Large areas of subpolar eastern Siberia, however, are also quite meadow-like in that they are open mosaics involving islands of larch woods or birch thicket within a matrix of forb-rich grassy cover. Grassland is indicated on the map for some of this area. The large area northeast of Kamchatka, though, has the outline of the Koryanskiy mountains and may only be alpine vegetation.

8. Semi-Desert and Desert Vegetation (brown)

Strictly speaking, true deserts have no vegetation but semi-deserts carry sparse vegetation. Nevertheless, some areas of mobile sand (as in the Tarim Basin) or extensive gravel (as in Dzungaria) that give a strong desert impression do carry some very sparse vegetation. Areas with no vegetation at all are included under "Bare Land" (below).

Semi-desert vegetation can be quite diverse in forms and seasonal patterns. In particular, in interior Eurasia, one might distinguish the following general types:

- Semi-Desert Scrub in Asia is largely desert shrubland on stable or somewhat mobile sand; the shrubs are often leafless (e.g. *Caragana*, *Haloxylon*) but can in fact be quite large, up to 2m high – or even higher if elevated by growing upward to escape the mobile sand. In such cases the shrubs end up atop "pedestals" of sand called 'nebkha'.

- Semi-Desert Dwarf Scrub is normally the most common form of desert vegetation, also in Asia, and consists mainly of smaller shrubs and dwarf shrubs widely scattered over the harsh physical substrate; the most important genus is probably *Artemisia* (wormwood; sagebrush in North America), most desert species of which have white-pubescent leaves and sometimes stems.

- Semi-Desert Grassland refers to sparse grass cover that is easily destroyed by overgrazing.

It was not possible to distinguish these sub-types on the map, but it may be possible in future work. Finally, some desert and semi-desert areas are traversed by dry streambeds that carry water occasionally and thus have higher groundwater levels. Such dry streambeds often carry trees, and in the Tarim Basin, for example, there can be prominent riparian forests of poplars (*Populus*). On the map, some of the brown pattern around the Tarim Basin suggests such riparian woods, especially on the northwest side (along the Yarkant and Tarim rivers); other peripheral brown areas represent foothills, where groundwater appears near the surface.

Tundra Vegetation (three shades of purple)

Tundra refers to treeless vegetation in the polar region or to analogous vegetation in the alpine belt of sufficiently high mountains. All plants in such climates must be adapted to a short, cool summer growing season and have mechanisms for winter dormancy. Nevertheless, tundra vegetation can be diverse; growth forms may include, in particular, summergreen shrubs (usually not higher than 50cm, of species in tree genera such as *Betula* and *Salix*); evergreen shrubs (also to 50cm, e.g. *Rhododendron, Ledum*) and dwarf shrubs (usually not higher than 20cm, mainly Ericaceae such as *Cassiope*); grasses and sedges (usually to about 50cm); small forbs (mostly summergreen, e.g. *Dryas*); mosses and lichens.

Polar tundra landscapes are usually mosaics, reflecting micro-relief, of two basic vegetation structures, described as grassy or sedge-moss tundra (occurring in wetter, flatter area) and dwarf-shrub tundra (occurring on more exposed uplands). The larger, summergreen shrubs mentioned above (*Betula* and *Salix*, etc.) appear near the southern limit of the tundra zone, where the growing season is longer. Exposed uplands with scattered dwarf-shrubs may have very low vegetation cover and can be described as sparse tundra, approximating the moss-lichen "polar desert" of the High Arctic zone, which has few vascular species.

Above treeline in temperate and high-latitude mountains, grassy tundra is restricted to flatter areas and may be less common (except on the high Tibetan Plateau, with enormous areas of alpine steppe dominated by the sedge *Kobresia*). In more complex terrain, the alpine vegetation is usually more mixed, with many microhabitats for very small plants.

Unlike the deserts, for tundra we did try to distinguish sub-types on the map, namely grassy, shrubby, and sparse tundra.

9. Grassy tundra (lavender)

This is essentially Arctic grassland (or more properly, sedgeland), constituted mainly by sedges (Cyperaceae), especially species of cotton grass (*Eriophorum*), which can be mono-dominant over enormous areas. Within the grassy sub-type we also include alpine steppes (as in Tibet) and alpine meadows, which are usually dense grassy swards but with many colorful forbs.

- Polar grassy tundra (typical)	This is indicated on the map across a wide area of northernmost Eurasia, from European Russia in the west to the Chukotka peninsula in the east; it is indicated mainly in flatter lowland areas but probably is shown too far south, since it is known that larch woods extend further north.
- Alpine Meadows	These are generally too small to appear at the scale of this map.
- Alpine Steppe	This should be shown on the Tibetan Plateau – but it is not.

10. Shrubby tundra (darker purple)

This refers to the generally taller, dense vegetation in warmer areas, involving both summergreen shrubs (of tree genera, e.g. *Salix*, *Betula, Alnus*) and scattered larger evergreen shrubs (e.g. *Rhododendron*). It also can be quite grassy and includes dwarf shrubs and small forbs where they can get enough light.

- Shrubby tundra	This is indicated on the map in some more southerly areas but also seems to follow the contours of various mountain ranges: northern Urals; the Byrranga (north) and Putorana (south) of the Taymyr region; various ranges in far eastern Siberia (most prominently the Orgulan-Verkhoyanskiy ranges just east of the Lena river.

11. Sparse Tundra (reddish purple)

This grouping includes, in principle, the polar cold deserts with mainly non-vascular vegetation (mosses and lichens), as well as alpine tundra (meadow plus dwarf shrubs) and alpine semi-desert and cold desert. The vascular vegetation is open and sparse, involving mainly small forbs, from genera such as *Dicentra*, *Polygonum*, *Papaver*, *Minuartia*, and *Saxafrag*.

Visually, we cannot identify this signature anywhere on the map.

12. Wetlands

Wetlands are areas where there is standing shallow water, extensively on the surface or at least in hollows of topography with Bult-Schlenke relief (micro-ridges and other tops surrounded by shallow micro-ditches, with maximum vertical difference not more than about 30cm). Wetlands may be wooded (e.g. swamps), but most are herbaceous (e.g. marshes, fens, wet meadows). Included, in particular, are the following types.

- Mires: Classic terrestrial wetlands, ranging from entirely rain-fed, highly acidic (bogs) to partially groundwater-fed and less acidic (fens); fen vegetation is overwhelmingly herbaceous, while bogs may be dominated by dwarf shrubs and forbs, especially Ericaceae

- Marshes	Herbaceous vegetation (e.g. *Phragmites, Typha*) in standing water
- Wet Meadows	Herbaceous vegetation in deeper standing water, sometimes involving floating or floating-leaved vegetation
- Saltmarsh	Coastal marshes involving especially *Spartina* species in seawater and *Juncus* species (and others) in brackish water

Most wetlands cover only small areas, and only a few herbaceous wetlands would appear on a map at this scale. It is impossible to separate the different types. The largest area of terrestrial wetlands is indicated in western Siberia, along the lower Ob' river and to its east. Also appearing on the map are the large marsh complex (mainly *Typha*) south of Qiqihar in western Manchuria and an area in western China near the boundaries of Gansu, Qinghai and Sichuan (i.e. at high elevation). Saltmarshes occur along coastlines in temperate Asia but are too narrow to appear on the map.

13. Mangroves (dark bluish purple)

Mangroves are woodlands or even tall forests, composed of particular salt-tolerant taxa that grow in the seawater of the inter-tidal zone. There are fewer than 100 such species worldwide and generally not more than about 10 in the narrow shoreline strips of primary mangrove that occur along many tropical shorelines. In Thailand especially, though, the primary mangrove may extend inland as far as 30 km and contain up to 30 species. These were also the tallest mangroves in the world, reaching 35m in height in areas protected from typhoons; due to human utilization, however, a more common height now is around 10m. The main mangrove genera, in Asia and worldwide, are *Rhizophora* and *Avicennia*, but Asia has a variety of other important mangrove tree genera as well, such as *Bruguiera*. More species occur in the less saline 'back mangroves' that lie behind the shoreline mangroves.

On the map, mangrove is indicated most clearly in west Bengal (south and southwest of Calcutta) but also along the Bay of Bengal coast of Myanmar and perhaps in the Malay peninsula (where areas do remain).

Cropland

Cropland includes both rice paddies and other crops. In this legend, paddy fields are shown separately as item 14 and other cropland (using that name) as items 15 and 16.

14. Paddy Fields

Rice paddies are an integral part of Asian landscapes and may cover extensive areas in river floodplains, coastal lowlands, and other relatively flat, low-lying areas. The biggest concentrations are in eastern China north of the Shanghai estuary; to the west around the large lake area of Hubei and Hunan (*hu* = lake in Chinese); further west in the Sichuan basin; and in Bengal.

15. Cropland (extensive)

Some cropland areas are quite extensive and may involve monocultures, such as the cereal-growing breadbasket of the Eurasian steppe zone and the densely settled East China Plain (between Beijing and Shanghai). The former was originally grassland, while the latter was originally mainly summergreen forest. Large cropland areas (light orange) are indicated on the map in eastern China (extensive but mixed cropping, with many vegetables); in Manchuria (mainly cornfields, fairly recent) and easternmost Inner Mongolia; and across southern Ukraine and Russia (cereals plus some vegetables) as far east as the Tian Shan mountains that separate Middle Asia from monsoon-influenced Central and eastern Asia.

16. Cropland Mosaic

Other crop areas are smaller, embedded in mosaic landscapes that may also involve woodlots and settlements. Such areas are indicated on the map (pink) in central China (e.g. Shaanxi, including the Xian area), in the Sichuan basin, and more scattered in southeastern China, including Hainan; in the Dry Belt of central Myanmar; over much of India; and in the Fergana basin and adjacent area around Tashkent in Uzbekistan.

Areas with Little or No Vegetation

17. Bare Land (including arid desert)

Bare land has no vegetation at all. This may be the driest parts of arid deserts, areas of recent volcanic activity that have not yet been re-colonized by vegetation, or some settled or industrial areas (mainly shown separately, as urban). The largest such areas are represented by the arid deserts of the Middle East (Arabia and Persia); the cold, high deserts of the Qinghai-Tibetan Plateau; and some parts of the Dzungarian-Gobi desert belt.

18. Ice Desert

Ice desert is land covered permanently by ice. The main areas in Eurasia are on the various islands of the Arctic Ocean: Novaya Zemlya (especially the northern part), Franz-Josef Land (north of Novaya Zemlya), and Severnaya Zemlya (north of the Taymyr peninsula). Only small areas of permanent ice appear in the Himalaya.

19. Open Water

Open water includes both seawater and freshwater lakes. Freshwater lakes visible on the map include Lake Baykal in Siberia, the Uvs and Hoevsgol lakes of northern Mongolia, Issyk Kul' in Kirghizstan, the Qinghai (blue lake, in Qinghai province) of western China; and the Hanka Lake on the border between Primorye and Chinese Manchuria. Brackish or more saline inland seas include the Caspian Sea, Lake Balkhash, and the Aral Sea (note its new shape and the small sea to its south, on the Amu Dar'ya river, which may represent extensive irrigation and is not shown in atlases).

20. Urban Areas

Urban areas have little vegetation but may nevertheless represent refuges for some species, mostly alien but some native. Their areas (in red) have been superimposed from another map. One can see clearly on the map that the largest is the Tokyo-Yokohama area.

References

Box, E. O. 1995. Global Potential Natural Vegetation: Dynamic Benchmark in the Era of Disruption. In: *Toward Global Planning of Sustainable Use of the Earth -- Development of Global Eco-engineering* (Sh. Murai, ed.), pp.77-95. Amsterdam: Elsevier.

Box, E. O., and K. Fujiwara 2005. Vegetation Types and their Broad-Scale Distribution. In: *Vegetation Ecology* (E. van der Maarel, ed.), pp. 106-128. Blackwell, Oxford.