Mapping a Mountain: Mt. Fuji Land Cover Transitions Over the 20th Century

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Abstract

From the alteration of the Mississippi River to the destruction of the amazon rainforest, resource demands and global commerce have led to landscape modifications. Among these changes lie biophysical constraints, which limit land use and land cover opportunities.

Little has been studied about how these global patterns impact volcanic landscapes, where steep slopes and soils with low water retention limit land use capabilities. This thesis documents land cover change on Mt. Fuji by quantifying and analyzing land cover change over the past century in between four different time periods: 1898, the 1930's, the 1950's and 1992. Land cover data were obtained by digitizing historic land cover maps of Fuji. These land cover mosaics were intersected with a digital map of the bedrock geology of Mt. Fuji to explore how geology has influenced observed land cover changes.

Croplands are concentrated in the few areas with water retention capabilities, and forests and grasslands dominate areas with low soil fertility and soil permeability. In the face of shifts in global resource demands, land uses that are more flexible to geologic constraints have led to dead ends. With limited land use alternatives, a recent increase in tourism may lead to land cover transitions that are more visitor friendly, and consequently, more profitable.

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Acknowledgements

This incredibly frustrating yearlong process would not have been worthwhile without the support of those who have guided me throughout.

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Finally, I would like to thank my family, for teaching me that it's ok to be lost.

Introduction

Globalization, Modernization and the Implications for Environmental Geography

Global commerce has led to staggering alterations of landscape patterns and processes. In cases like the Mississippi River, landscapes have been readily manipulated; in contrast, in cases like Mt. Fuji, geologic constraints limit economic opportunities.

In 1831, the U.S began to alter the Mississippi River's passageway and created shortcuts for navigation, dredged channels, implemented dams and levees.[1] This added nearly 145 miles to the route of the Mississippi, which is still used as a business turnpike today.[2] Similarly, the Columbia River has been modified for electrical power and now contains 14 dams on its main stream.[3] Scenarios such as this these where commerce leads to modifications of ecological systems are not uncommon. Regions that once consisted of temperate forests now contain bustling cities and those which were dominated by savannahs and deserts are now heavily irrigated croplands.

In this thesis, I will explore the causes and implications of land cover change of a landscape in Japan: Mt. Fuji. Japan is an intriguing place to investigate land cover change for a variety of reason. First, it is a geographically constrained setting. The island nation is mountainous, but has a large population (approximately 127.6 million), which occupies all available non-rugged terrain.[4] Mt. Fuji acts as a microcosm of Japan, the skirts and lower lying areas of the volcano are habitable but geologic constraints underlie land use opportunities. Second, in recent history, Japan has been a strong and stable state, one that is able to control land tenure structures, subsidies, and resource security strategies. Mt. Fuji in particular is a place where land tenure patterns and resource security goals have been instituted. Third, Japan's involvement in World War II, and the following U.S occupation led to land reform policies that influenced land use and land cover patterns on Mt. Fuji and other areas in Japan.[5]

I will document land cover change on Mt. Fuji over the past 100 plus years using Geographical Information Systems (GIS) and interpret land cover change in light of drivers at

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[1] McPhee, John. The control of nature. Macmillan, 2011

[2] Zaninetti, J. M., R. H. Kesel, E. G. Yodis, and A. T. Ngo. "Environmental Manipulations and their Consequences for the Mississippi River Delta.

[3] Ruggerone, Gregory T. "Consumption of migrating juvenile salmonids by gulls foraging below a Columbia River dam." Transactions of the American Fisheries Society 115, no. 5 (1986): 736-742.

[4] Eberstadt, Nicholas. "Demographic Future-What Population Growth-and Decline-Means for the Global Economy, The." Foreign Aff. 89 (2010): 54.

[5] Kingston, Jeff. "Transformations After World War II." Contemporary Japan: History, Politics, and Social Change since the 1980s 14 (2012): 1

diverse scales and local geologic constraints. I argue that geologic constraints limit flexibility of land use transitions in the face of shifting patterns of resource demand.

Global land cover change has had noticeable environmental consequences, and the degree of impact varies based on area, type of change and land use practices. Some environmental issues that arise from land cover changes include greenhouse-gas emissions, soil alteration, reduced water quality, biodiversity loss and habitat degradation. Practices such as soil oxidation and forest clearance increase CO_2 levels; rice paddies and livestock release methane and fertilizers increase N_2O.[6]

Both macro and micro climatic changes have been attributed to land cover transformations. Macro-effects of land cover change occur through greenhouse gas emissions, while micro-effects are related to regional forest clearance that reduce precipitation and increase temperature. For example, in the Costa Rican part of the San Juan basin, 72% of the area has been converted from tropical forest to pasture and cropland.[7] This had led to a reduction of evapotranspiration (water transfer from plants and surrounding soil to the atmosphere) which has led to an increase in temperature and decrease in precipitation.[8] Erosion, caused by a decrease of vegetative cover is common in arid and semi-arid climates, where wind can deform terrain and displace topsoil.[9] Analyzing land cover transformations and impacts can teach us how to utilize land in ways that reduce these and other consequences.

Drivers of Change

Observable land cover transformations are driven by changes in population growth, available technologies, connections between producers and the market, taxes and subsidies. Since the early 20th century, the world has experienced rapid urbanization and the proportion of the global population living in urban areas has increased from 2.5% in 1800 to 50% in 2008.[10] These numbers fluctuate geographically. Nations that have experienced rapid industrialization over the past century have greater than 68% of their population within urban areas, while

[6] Smith, K. A., and F. Conen. "Impacts of land management on fluxes of trace greenhouse gases." Soil Use and Management 20, no. 2 (2004): 255-263.
[7] Lawton, Rous. Nair, R. A. Pielke Sr, and R. M. Welch. "Climatic impact of tropical lowland deforestation on nearby montane cloud forests." Science 294, no. 5542 (2001): 584-587
[8] Ibid.
[9] Wolfe, Stephen A., and William G. Nickling. "The protective role of sparse vegetation in wind erosion." Progress in physical geography 17, no. 1 (1993): 50-68
[10] Annez, Patricia Clarke, and Robert M. Buckley. "Urbanization and growth: setting the context." Urbanization and growth (2009): 1.

economically poorer regions have only recently begun to experience an increase in urbanization and urban migration.[11]

Urbanization is not only a proxy for industrialization, but also a driver of land use and land cover change. As nations experience rapid urbanization, rural areas are often either transformed or abandoned. For example, socio-economic migration and rural depopulation led to abandonment of agricultural land in Spain, Central Mexico, Western Europe, Italian Alps and Ireland.[12] Cropland abandonment can lead to desertification, biodiversity loss and an increase of fire frequency, but may also pave paths towards reforestation practices.[13]

Many rural towns and villages are slowly dying out due to the urban out-flow. In most nations, rural areas have a disproportionately greater number of elderly individuals than urban areas. In Japan over one quarter of those counted in the "core agricultural labor force" are over 60 and less than 6 percent are under 30.[14] Regions once full of small rural communities are slowly transforming into highly urbanized societies.

Population growth, resource needs and global market structures have also motivated global land cover transitions. The production of cereal crops has more than tripled since 1950, and over the past three decades, the average per capita food availability has increased from approximately 2400 calories to 2700 calories per capita per day.[15] This rise has been fostered by technological gains (fertilizer, pesticides, irrigation, transportation, etc.) coupled with a global land cover transition from forests and savannahs to agricultural croplands. Over the 20th century, croplands expanded by 50% from approximately 1200 million hectares in 1900 to 1800 million hectares in 1990.[16] These shifts have occurred primarily in nations with productive soils and adequate climate conditions such as United States, Australia, China, and Argentina, among other countries.[17]

Deforestation, especially in the tropics, has been another prevalent land cover transition. Expanding infrastructure, trade, debt, growing population pressures, fuel wood dependency and food and land shortages are key factors leading to deforestation practices. Between 1980 and

[11] Ibid.
[12] Benayas, JM Rey, Ana Martins, Jose M. Nicolau, and Jennifer J. Schulz. "Abandonment of agricultural land: an overview of drivers and consequences."*CAB Rev Perspect Agric Vet Sci Nutr Nat Resour* 2 (2007): 1-14
[13] Ibid.
[14] Dore, Ronald. Land reform in Japan. A&C Black, 2013.
[15] Naylor, Rosamond L. "Energy and resource constraints on intensive agricultural production."Annual review of energy and the environment 21, no. 1 (1996): 99-123.
[16] Ramankutty, Navin, Jonathan A. Foley, and Nicholas J. Olejniczak. "People on the land: Changes in global population and croplands during the 20th century."AMBIO: A Journal of the Human Environment 31, no. 3 (2002): 251-257
[17] Ibid.

1990, over 154 million ha of forest cover disappeared (an area three times the size of France).[18] As societies industrialize, forest area decreases and after a threshold of development is reached, returns as secondary forests.[19] This pattern of forest cover has been called "the forest transition." It is argued that as urbanization and industrialization pull people from agricultural lands, these lands to revert back to forests, or become forest plantations. This process of forest transition (destruction and regrowth) has been accelerated by globalization, in which forest losses in one area can foster regrowth in another.

Biophysical Constraints

Drivers of land cover change are often limited by biophysical constraints that impede cultivation and urbanization, regardless of agricultural technologies and government subsidies. Japan, an island nation located at the intersection of three tectonic plates, is not without geologic constraints. Biophysical constraints include climate, steep slopes, and high soil permeability. For example, croplands are largely absent in areas with dry or cold climates; subtropical deserts, high alpine regions and high-latitudes are all regions without agricultural cultivation. Mountainous and volcanic regions often pose geologic constraints on land cover options.

In the American Southwest, cinder cone eruptions affected prehistoric societies and their agricultural production, decreased soil fertility and increased soil permeability.[20] The impact of these events depended on the thickness of the tephra fallout and community responses. [21] Tephra fallout between three and eight centimeters improved soil nutrient attributes by regulating soil temperature, lowering pH and providing an increase in phosphorous, while "thick cinder blankets" can leave impacted areas uninhabitable.[22] Steep slopes limit transportation and technological accessibility and increase landslide and erosion potential. For instance, in Lesvos, Greece, there are severely eroded soils in areas with slopes greater than 12 degrees, and areas with steeper slopes had greater areas of cropland abandonment.[23]

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[18] Tole, Lise. "Sources of deforestation in tropical developing countries." Environmental Management22, no. 1 (1998): 19-33.

[19] Grainger, Alan. "The forest transition: an alternative approach." Area (1995): 242-251; Mather, Alexander S., and C. L. Needle. "The forest transition: a theoretical basis." Area 30, no. 2 (1998): 117-124; Rudel, Thomas K. "Is There a Forest Transition? Deforestation, Reforestation, and Development 1."Rural sociology 63, no. 4 (1998): 533-552.

[20] Ort, Michael H., Mark D. Elson, Kirk C. Anderson, Wendell A. Duffield, and Terry L. Samples. "Variable effects of cinder-cone eruptions on prehistoric agrarian human populations in the American southwest." Journal of Volcanology and Geothermal Research 176, no. 3 (2008): 363-376

[21] Ibid.

[22] Ibid.

[23] Bakker, Martha M., Gerard Govers, Costas Kosmas, Veerle Vanacker, Kristof van Oost, and Mark Rounsevell. "Soil erosion as a driver of land-use change." *Agriculture, ecosystems & environment* 105, no. 3 (2005): 467-481

Often, however, geologic constraints are not unworkable, but land use substitutes are narrowed. For example, a community located in an area with low water retention will be limited to producing crops that are water less independent (timber plantations); thus, they may have no other option than to engage in forestry. Japan, with little land available for agriculture, has employed timber cultivation on many of its steep and mountainous landscapes.

Setting the Scene: Japan and the Move Towards Modernization

Japan is a young volcanic island nation.[24] About 80% of Japan is composed of hillside and upland topography.[25] Regardless of its mountainous terrain and geologic hazards, Japan is one of the most urbanized and modernized societies in the world.[26] Almost two-thirds of the Japanese population lives in 3% of Japan's land and 91.3% resides in urban areas.[27] Throughout the late 19th and 20th century, the human geographical changes in Japan were rapid, as was the path to industrialization and urbanization. The Meiji Restoration, reclamation of Japanese imperial rule (1868-1912) paved the way towards modernity, (in which a strong state was maintained and the pace of innovation accelerated.)[28] By 1890, manufacturing industries were established and Japan had begun to close the economic gap with already modernized western societies. Much of Japan's economic development can be attributed to the transition from agricultural raw material exports to textiles and manufactured goods.[29] This transition was enabled by a shift from a long period of isolation to the "opening of the west". During the late 19th century, the Japanese government began to build factories, which were equipped with Western machinery and launched educational reforms, which followed French and German models.[30]

Much of the modern day "westernization" of Japan was not welcome by Japanese citizens because traditional customs and national pride were perceivably threatened.[31] In 1930, the Japanese were openly suspicious of the capitalistic ideologies of the west, although during the Meiji Restoration, many Meiji leaders looked to the west for inspiration and lessons about

[24] Kaizuka, S. "Late cenozoic palaeogeography of Japan." GeoJournal 4, no. 2 (1980): 101-109.
[25] Totman, Conrad D. Early Modern Japan. Univ of California Press, 1995
[26] Totman, Conrad. "Plantation forestry in early modern Japan: economic aspects of its emergence." Agricultural history (1986): 23-51.
[27] Karan, Pradyumna Prasad, and Kristin Eileen Stapleton. The Japanese City: Nihon No Toshi. University Press of Kentucky, 1997
[28] McClain, James L. Japan, a modern history. WW Norton & Company, 2002.
[29] Ibid.
[30] Ike, Nobutaka. "Taxation and Landownership in the Westernization of Japan." The Journal of Economic History 7, no. 02 (1947): 160-182
[31] Ikegami, Eiko. "Citizenship and national identity in early Meiji Japan, 1868-1889: a comparative assessment." International Review of Social History 40 (1995): 185-222.

how to organize political institutions and foster wealth.[32] The tensions between a perceived need to engage with global economic systems and nationalist and traditional views were fostered by goals to limit international dependency, but also to compete militarily and economically with nations of the west. World War II highlights a period of unwanted western influence and control in competition with national goals of resource security and wealth.

Although heavy industry gave shape to many of these transitions, agrarian societies were influential and arguably essential for Japan's modernization.[33] Between 1878 and 1920, land used for cultivation of cropland increased by 35% and land productivity increased by 80%, which shows that gains from technology were more important than new, available land.[34] These gains made a necessary contribution to the expansion of international trade, and commercial products such as silk cocoons and tea leaves were the basis for rapid growth of manufactured exports.[35] Before World War II, Japan's primary exports were agricultural commodities. To this day, traditional cultivation practices are still utilized in Japan. Many of these customs are dominated by rice plantations, forestry and other forms of cultivation, often practiced on village common lands.

Managed forestlands, common grasslands and various agricultural croplands are located on the slopes and base of Mt. Fuji. As a popular tourist attraction and cultural icon, Mt. Fuji provides a unique narrative of land use and land cover change during 20th century. Land cover is dictated by both global patterns of exchange and national goals, but is also constrained by what local or regional conditions permit. Some issues of soil fertility or pest abundance can be overcome with fertilizers and pesticides, but some issues are much more difficult to overcome, like soil permeability.

As a microcosm of Japan, Fuji is composed of porous volcanic lava, an example of a location constrained by stubborn conditions. These limitations represent the eruptive past of a young volcanic landscape.

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32 Gluck, Carol. Japan's modern myths: ideology in the late Meiji period. Princeton University Press, 1985.
33 McClain, James L. Japan, a modern history.
34 Ohkawa, Kazushi, and Henry Rosovsky. "The role of agriculture in modern Japanese economic development." *Economic Development and Cultural Change* 9, no. 1 (1960): 43-67
35 Ibid.

Fuji: An Eruptive Past

Mt. Fuji lies near the junction of the Eurasian, Philippines, Pacific and North American plates.[36] Subduction of the Philippine Sea plate beneath the Eurasian plate replenishes the magma beneath Mt. Fuji. Mt. Fuji is a composite stratovolcano consisting of Pre-Komitake (several 100 thousand years ago), Komitake (>100 thousand years ago) and Fuji (100 thousand years ago) (Figure 1.).[37] Fuji is known for its conical shape, a form that is attributed by its past eruptions of non-viscous, mafic lava, and consists of a variety of parasitic cinder cones, which are aligned northwest-southeast.[38]

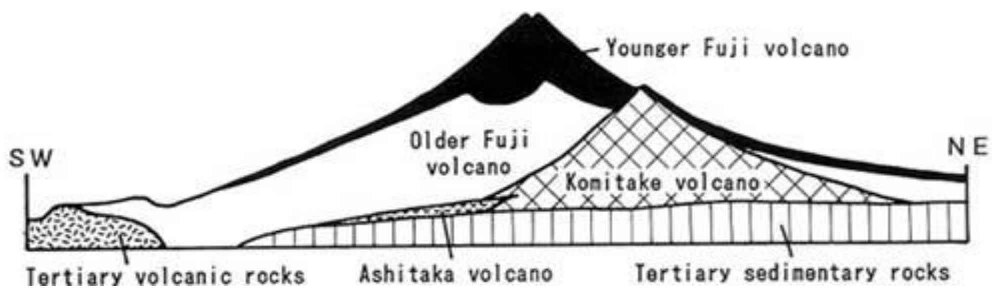

Figure 1. Cross section of Mt. Fuji (by Miyaji et al., 1992).

The first known eruption at the site of Mt. Fuji happened over 600,000 years ago at the Komitake volcano.[39] This eruption included lava (olivine-basalt), volcanic ash, pumice, volcanic sand lapilli and volcanic mud.[40] About 200,000 years ago, Older Fuji volcano began erupting. [41] These eruptions distributed mudflows and lava in all directions of the mountain, giving Fuji its conical shape. Between 100 thousand years ago and 17 thousand years ago, Older Fuji erupted multiple times and the episodes have been characterized as explosive.[42] These eruptions included wide spread scoria falls that extend from the eastern flank of Fuji to the Kanto Plain.[43] The Kanto Plain is the most populated region of Japan and contains several large cities,

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[36] Oguchi, Takashi, and Chiaki T. Oguchi. "Mt. Fuji: The Beauty of a Symmetric Stratovolcano." In*Geomorphological Landscapes of the World*, pp. 303-309. Springer Netherlands, 2010
[37] Ibid.
[38] Chesley, Christine, Peter C. LaFemina, Christine Puskas, and Daisuke Kobayashi. "The 1707 Mw8. 7 Hoei earthquake triggered the largest historical eruption of Mt. Fuji." *Geophysical Research Letters*39, no. 24 (2012)
[39] Chen, Shu, and Hoson Kablawi. "The secret behind the mountain Mt. Fuji." Introduction to "Magical locations"- linking people and places: 36.
[40] Kuno, Hisashi. "Petrology of Hakone volcano and the adjacent areas, Japan." Geological Society of America Bulletin 61, no. 9 (1950): 957-1020.
[41] Le Bas, M. J. "Quaternary to Recent volcanicity in Japan." Proceedings of the Geologists' Association 93, no. 2 (1982): 179-194
[42] Cities on Volcanoes. 2007. Field trip guidebook Cities of Volcanoes 5 Conference, Shimabara, Japan, November 19-23, 2007. Tokyo: Volcanological Society of Japan.
[43] Ibid.

including Tokyo.[44]

Between 15,000 and 6,000 BC, Younger Fuji was constructed and erupted several lava flows which were characterized by smooth fluid lava flows.[45] Between 1300 and 1000 BC, explosive flank eruptions occurred on the northwestern and southeastern flanks and are characterized by scoria (vesicular volcanic rock).[46] At around 1000-900 BC, the eastern flank of the volcano collapsed, which formed the Gotenba debris avalanche.[47] After this collapse, there were numerous explosive eruptions from the summit. Prior to 700 AD, these eruptions occurred more frequently on the eastern-northeastern flank.[48] The two most recent eruptions, the Jogan in 864 AD and Hoei in 1707, characterize much of the current geologic landscape.

Jogan Eruption

The Jogan Eruption is one of the most well known eruptions that occurred on Mt. Fuji and was localized on the northwestern foot of the volcano. At the same time as the Jogan eruption, Kenmarubi lava flow erupted from a different vent on the northern flank of Fuji.[49] The area covered by the lava flow (30 km^2) is now called the Aokigahara wood-sea and is almost impenetrable.[50] The Kenmarubi lava flow is an example of a flow in which people funneled mudflows to decrease permeability and make the land arable.

Hoei Eruption

The 1707 Hoei eruption is the most recent eruption of Mt. Fuji. The Hoei eruption has been described as "sub-plinian" eruption.[51] Plinian eruptions are characterized by powerful plumes of ash and debris. Generally, Plinian eruptions generate eruptive columns greater than 30 kilometers and widespread dispersals of tephra.[52] The Hoei eruption began on December 16,

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[44] Kurita, Hideharu, Makoto Yokohari, and Jay Bolthouse. "The potential of intra-regional supply and demand of agricultural products in an urban fringe area: a case study of the Kanto Plain, Japan."*Geografisk Tidsskrift-Danish Journal of Geography*109, no. 2 (2009): 147-159.

[45] Yamamoto, T., A. Takada, Y. Ishizuka, N. Miyaji, and Y. Tajima. "Basaltic pyroclastic flows of Fuji volcano, Japan: characteristics of the deposits and their origin." Bulletin of volcanology 67, no. 7 (2005): 622-633.

[46] ibid.

[47] Miyaji, Naomichi, Shigeko, Togashi, and Tatsuro. Chiba. "A large-scale collapse event at the eastern slope of Fuji volcano about 2900 years ago." Bull. Soc. Volcanol. Jpn 49 (2004): 237-248

[48] Cities on Volcanoes. 2007

[49] Kobayashi, Makoto, Akira Takada, and Shun Nakano. "Eruptive history of Fuji Volcano from AD 700 to AD 1,000 using stratigraphic correlation of the Kozushima-Tenjosan Tephra." Bull. Geol. Surv. Japan 57 (2007): 409-430

[50] Fuji, Mt. "3. Mt. Fuji.

[51] Suzuki, Yuki, and Toshitsugu Fujii. "Effect of syneruptive decompression path on shifting intensity in basaltic sub-Plinian eruption: Implication of microlites in Yufune-2 scoria from Fuji volcano, Japan." Journal of Volcanology and Geothermal Research 198, no. 1 (2010): 158-176.

[52] Walker, G. P. L. "Plinian eruptions and their products." Bulletin volcanologique 44, no. 3 (1981): 223-240; Sparks, R. S. J. "The dimensions and dynamics of volcanic eruption columns." *Bulletin of Volcanology*48, no. 1 (1986): 3-15

1707 and continued for 15 days.[53] It occurred at the SSE-flank.[54] The ejected ash was carried by prevailing winds as far as Yedo, (old Tokyo) 100 km to the east.[55] The volume of debris has been estimated at .7 km^3.[56] The eruption was one of the largest in Mt. Fuji's history and was followed by numerous lahars, characteristic of Plinian eruptions.[57] This eruption produced no lava or pyroclastic flows.[58]

The 1707 eruption heavily influenced the land of Fuji and its surrounding areas. The number of houses in the impacted area decreased by one third and the Sakawai River, which flows along the eastern foot of Mt. Fuji, flooded for 80 years after the eruption.[59] The tephra from this event still covers much of the south Kanto Plain and has improved soil permeability in this region.[60]

The geologic history of Mt. Fuji plays a role in land utilization and land cover of this young volcanic landscape. The vegetation on Mt. Fuji still bears an imprint of the Hoei eruption. Above 2000 meters in elevation, most of the ground between trees is bare scoria.[61] Mt. Fuji contains no alpine plants, which can be attributed to its porous lava, sand and lapilli, which leave the soil incapable of sufficient moisture retention.[62] While previous studies have investigated how the soil and geologic conditions of Fuji constrain alpine species, few have explored how the geologic stratum has influenced land cover and land cover transitions

Methodology: Mapping a Mountain

My methodology is split into two parts. The first part analyzes land cover transitions on Mt. Fuji over the 20th century and compares patterns of land change on Mt. Fuji to shifts in national and global commerce. The second part investigates the bed rock geology and its influence on land cover. Geologic strata intersected with land cover types can help determine which geologic base layers are more conducive to different land cover types.

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53 Miyaji, Naomichi. "The 1707 eruption of Fuji volcano and its tephra." Global Environmental Research-English Edition- 6, no. 2 (2002): 37-40.
54 Tsuya, Hiromichi. "Geological and Petrological Studies of Volcano, Fuji, V.: 5. On the 1707 eruption of Volcano Fuji." (1955).
55 Totman, Conrad. Japan: An Environmental History.
56 Yamamoto, T., A. Takada, Y. Ishizuka, N. Miyaji, and Y. Tajima. "Basaltic pyroclastic flows of Fuji volcano, Japan: characteristics of the deposits and their origin."
57 Miyaji, N. "Wind effect on the dispersion of the Fuji 1707 tephra." Bull Volcanol Soc Jpn 29 (1984): 17-30.
58 Miyaji, Naomichi. "The 1707 eruption of Fuji volcano and its tephra."
59 Ibid.
60 Shoji, Sadao, and Tadashi Takahashi. "Environmental and agricultural significance of volcanic ash soils." Global Environmental Research-English Edition- 6, no. 2 (2002): 113-135.
61 Wardle, P. "Japanese timberlines and some geographic comparisons."Arctic and Alpine Research (1977): 249-258.
62 Masuzawa, Takehiro. "Ecological studies on the timberline of Mt. Fuji." The botanical magazine= Shokubutsu-gaku-zasshi 98, no. 1 (1985): 15-28.

Part 1. Land Cover Change

I observed for land cover four decades: 1890's, 1930's, 1950's and 1990's. Land cover change between these periods was analyzed. This allowed for successive change to be observed and calculated. Original land cover maps produced by the Kokudo Chirrin, known as the Geophysical Survey Institute of Japan (Figure 2.) were obtained for each decade. The Fuji area spans four maps, henceforth referred to as quadrants (southwest, northwest, southeast and northeast). The quadrants composed an area of 1680 km^2. Land cover boundaries (polygons) were traced by hand for each quadrant. For 1898 and 1992, all quadrants were from the same year, while for the 1930's and 1950's, quadrants were not uniform by date (1930's: SW 1930, NW 1930, SE 1933, NE 1933 ; 1950's: SW 1959, NW 1959, SE 1954, NE 1960).

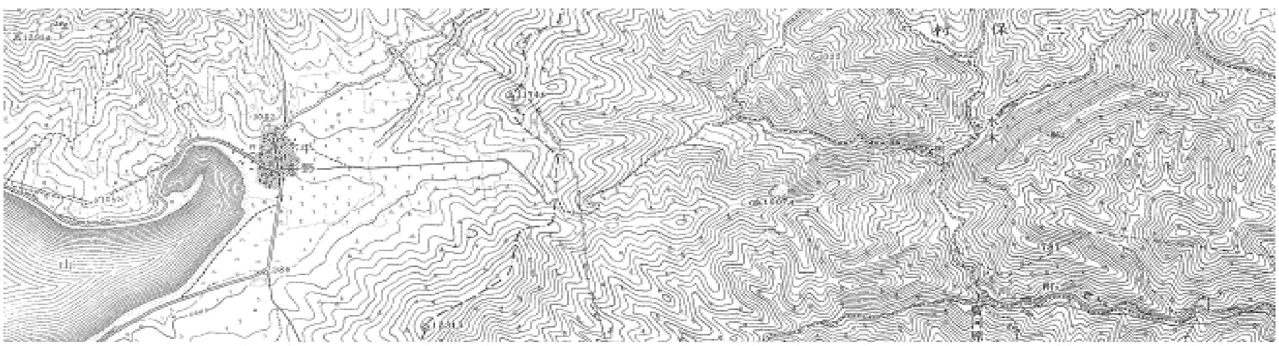

Figure 2. An example of an original land cover map produced by the Kokudo Chiriin. Different symbols represent different land cover type.

Like much of Japan, land cover around Mt. Fuji consists of both cultivated lands and non-cultivated forests. Based on historical land cover maps, land cover of Fuji can be narrowed into 13 observable categories:

Land Cover Type	Description
Bamboo	**See dwarf bamboo*
Boulder	Areas with basaltic and andesitic rock w/o vegetation.
Broadleaf-Coniferous Forest	Areas with both coniferous and broadleaf species.
Broadleaf Forest	Deciduous tree species, include the Japanese Blue Beech (*F. Japonica) and* Mongolian Oak (*Quercus mongolica).*[63]
Coniferous Forest	Subalpine coniferous forests are prominent in Japan. Common species include Northern Japanese Hemlock(*Tsuga diversifolia)* and Veitch's Silver Fir (*Abie veitchii*), other species include: *Abies homolepis*, *Tsuga sieboldii* and *Abies firma*.[64]
Dwarf Bamboo	Dwarf bamboo (*Sasa*), is the most common forest floor cover in Japan.
Field	Cultivated areas used for cereals and vegetables.
Lake	There are 5 lakes on Mt. Fuji: Lake Yamanaka, Lake Motosu, Lake Shoji, Lake Sai and Lake Kawaguchi.
Mitsumata (*Edgeworthia chrysantha)*	A deciduous shrub with yellow fragrant flowers. Bark is used for traditional Japanese tissue paper.[65]
Mulberry Plantation	Leaves from mulberry trees are the only food source of the silkworm, the cocoon of which is used to produce silk.
Rice Paddy	Rice is a staple of the Japanese diet. Rice paddy areas consist of a holding pond that collects water from hillsides and ditches which run water along the rice fields.[66] It requires lots of rain and irrigation water.
Tea Plantation *(Camellia sinensis)*	Fields of flowering plants which produce, white, green, black and yellow tea. Forty percent of tea production in Japan occurs in the Shizouka prefecture.[67]
Wasteland	Traditional common grasslands used for horse grazing, charcoal and thatch for roofs.

Figure 3. Fuji land cover descriptions.

[63] Hukusima, Tukasa, Tetsuya Matsui, Takayoshi Nishio, Sandro Pignatti, Liang Yang, Sheng-You Lu, Moon-Hong Kim, Masato Yoshikawa, Hidekazu Honma, and Yuehua Wang. "Syntaxonomy of the East Asiatic Fagus Forests." In Phytosociology of the Beech (Fagus) Forests in East Asia, pp. 9-47. Springer Berlin Heidelberg, 2013.
[64] Miyawaki, Akira, Kunio Suzuki, and Kazue Fujiwara. "Human impact upon forest vegetation in Japan." Le Naturaliste Canadien 104 (1977): 97-107
[65] Murakami, Yayoi. "The development of improved and specialized Japanese paper during the Meiji era [1968-1912]." Journal of the Japanese Forest Society (Japan) (2006)
[66] Hanks, Lucien M., and Lucien Mason Hanks. Rice and man: agricultural ecology in Southeast Asia. University of Hawaii Press, 1992.
[67] Pitelka, Morgan, ed. Japanese Tea Culture: Art, History and Practice. Routledge, 2013.

Land cover types were represented by differing symbols on the Kokudo Chirrin map, some of which were difficult to distinguish because of their similarity. To maintain consistency when tracing the historical land cover maps, I declared a personal “data resolution” and ignored single land cover symbols, recognizing blocks of at least 3 contiguous symbols, which is approximately $4m^2$. If land cover types shared the same area, I combined them (this was only necessary for broadleaf and coniferous forest land cover categories.) After tracing land cover polygons by hand, I scanned the maps and georeferenced on ArcMap 10. The georeferenced]maps were vectorized, and polygon layers of land cover type were created. Polygon layers were then converted into gridded data for further analysis (figures 3-7). These figures provide a visual narrative of land cover change on Mt. Fuji throughout the 20^{th} century.

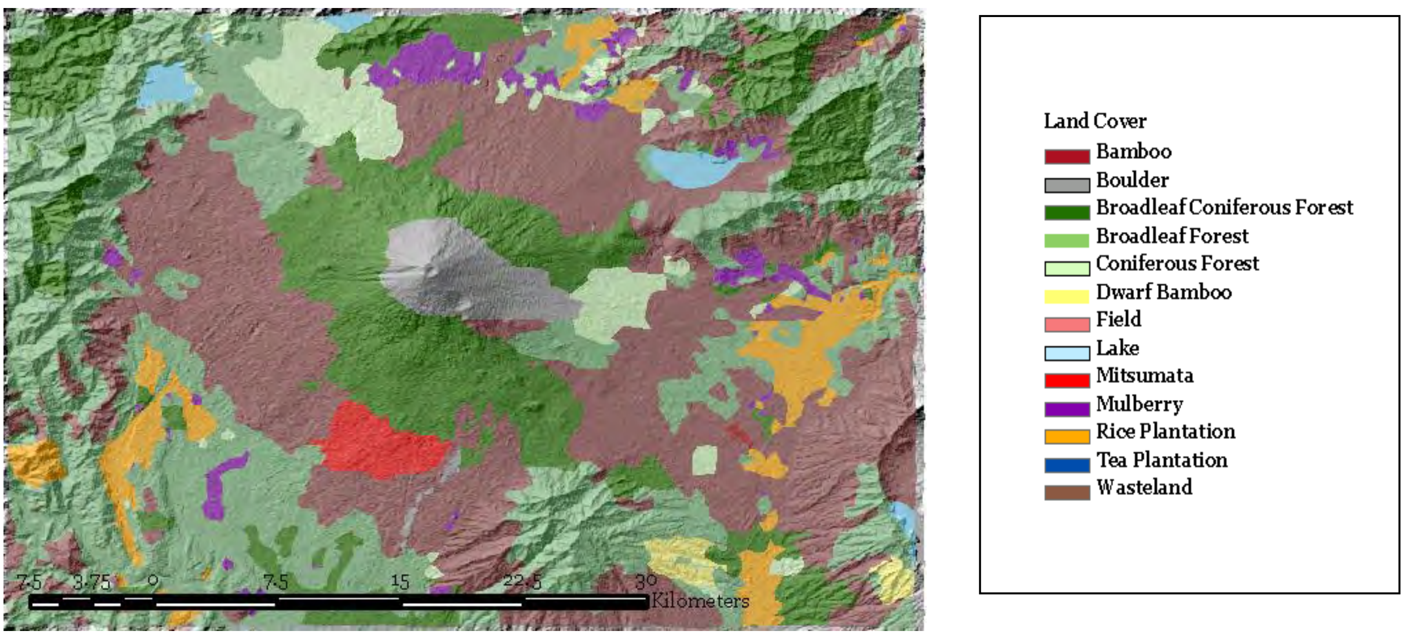

Figure 4. Mt. Fuji land cover during 1898.

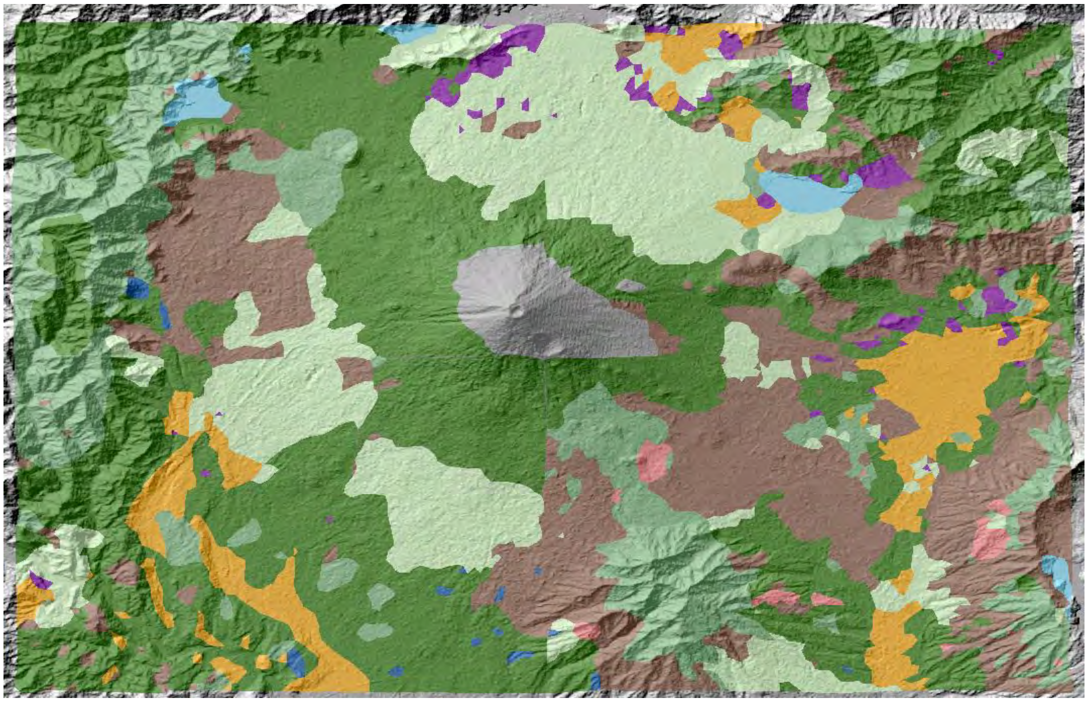

Figure 5. Mt. Fuji land cover during the 1930's

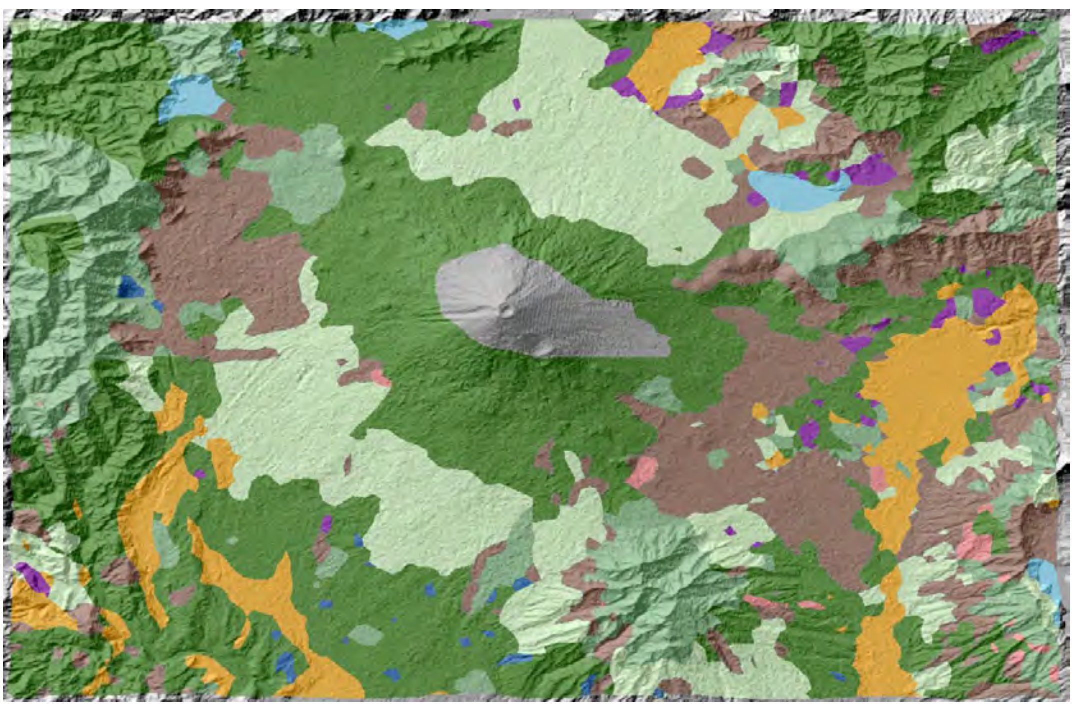

Figure 6. Mt. Fuji land cover during the 1950's.

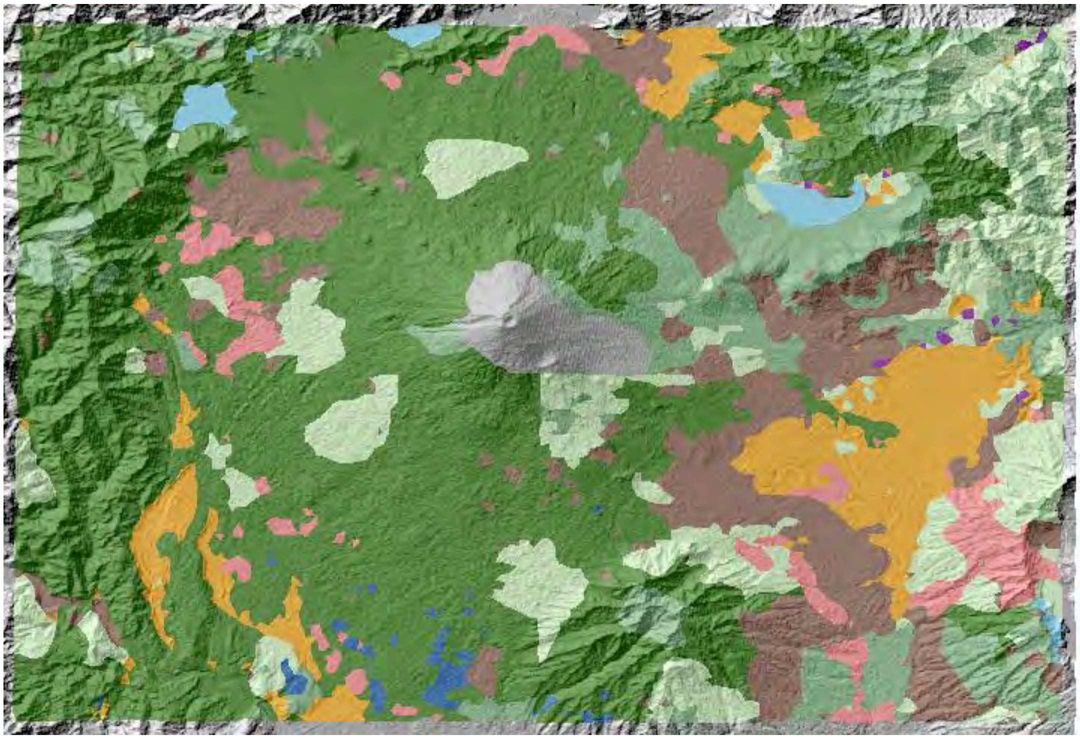

Figure 7. Mt Fuji land cover during 1992.

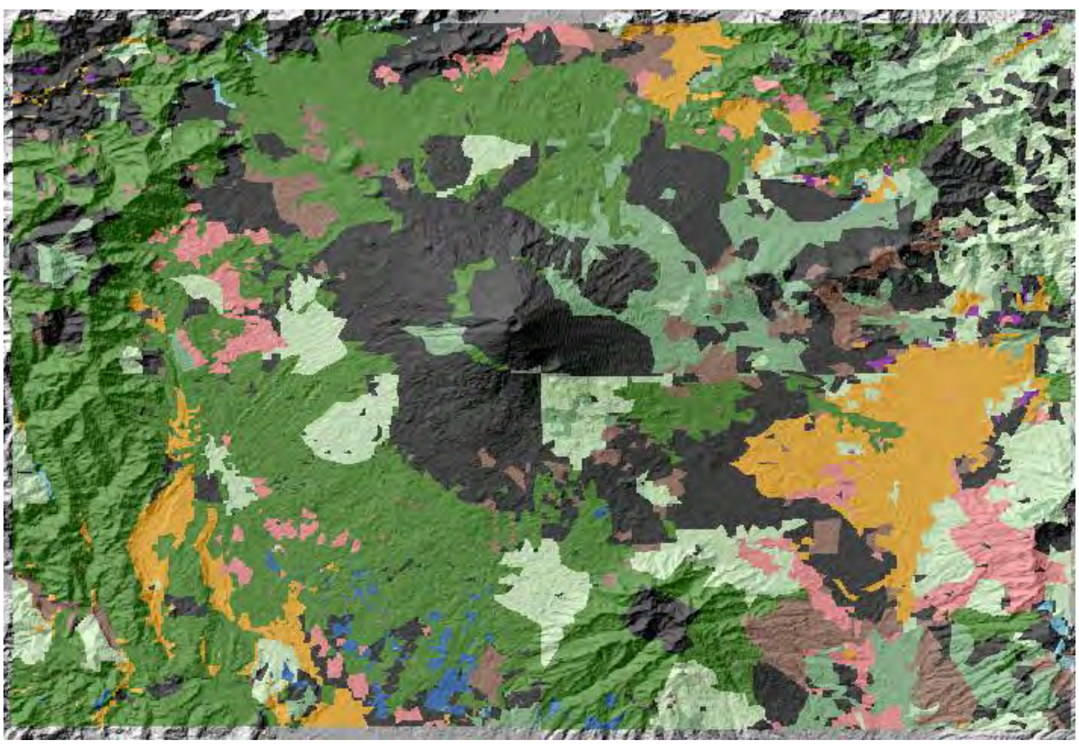

Figure 8. Mt Fuji land cover change between 1898 and 1992. Black portions represent areas of no change.

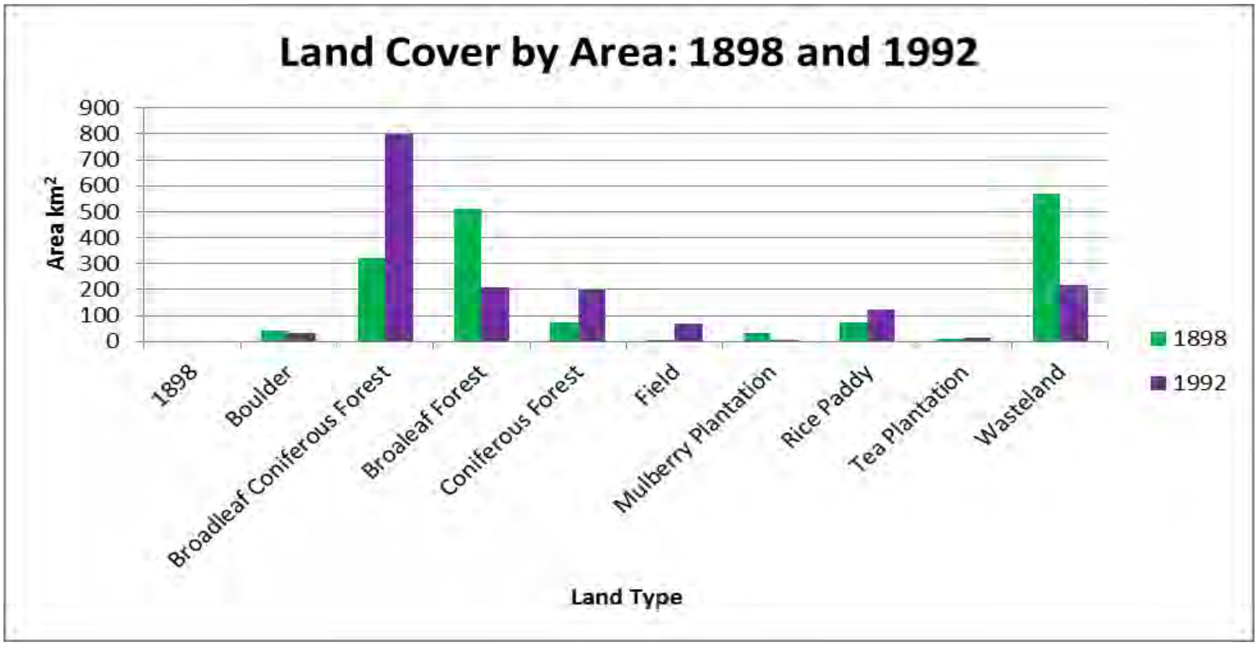

Figure 9. Land cover by area for 1898 and 1992.

Land cover data were analyzed in two ways: relative land cover change (% change for each land type) and land cover transitions (absolute area of change). First, relative land cover change was calculated for each land cover type that was observed in all four decades. For example, to calculate relative land cover change between 1898 and 1992 the following equation was used:

(1992 area km sq-1898 area km sq)

--- x 100 = % change

1898 area km sq

Relative land cover change was computed for four time periods: 1898-1930's, 1930's-1950's, 1950's-1992 and 1898-1992.

Overall, coniferous forests, mixed broadleaf coniferous forests, rice plantations and field had the greatest increase in area while wasteland, mulberry plantations and broadleaf forests showed considerable decrease in area during this 100 year period.

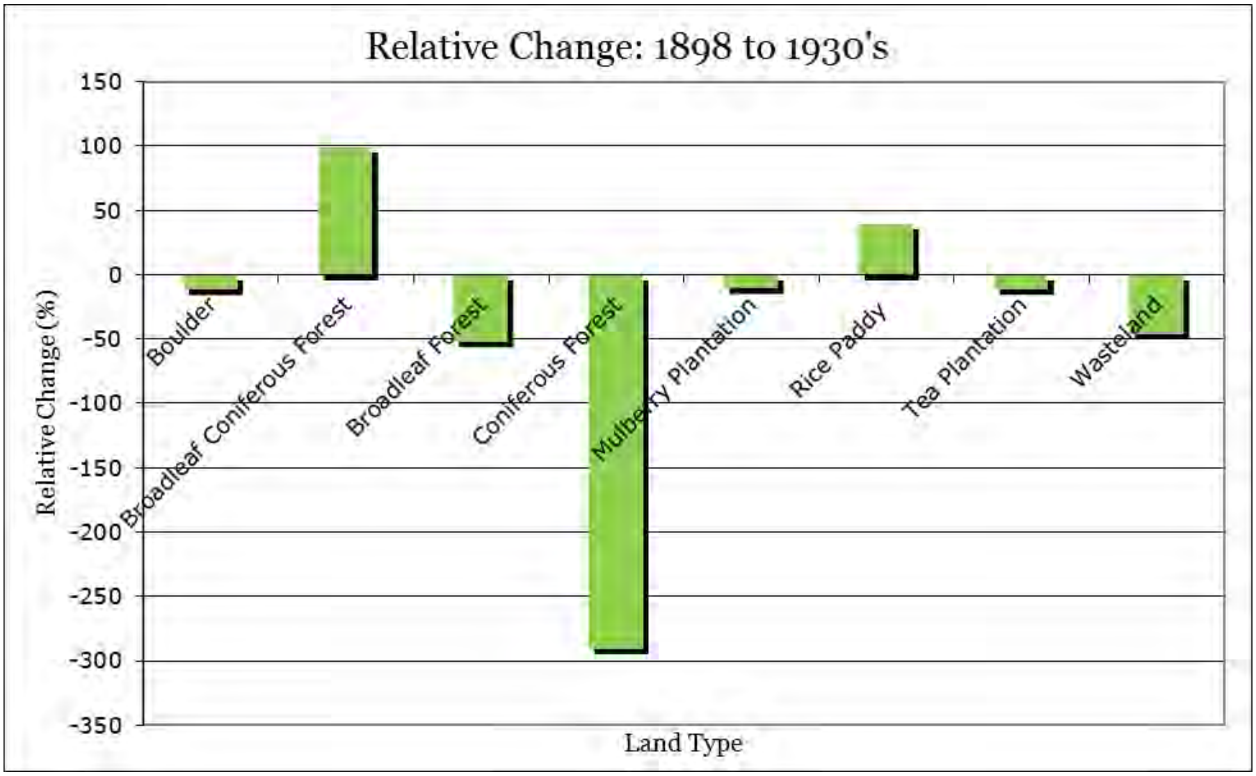

Figure 10. Relative land cover change between 1898 and 1930. Field areas had a relative change of 2304% and were not included in this figure because of scale.

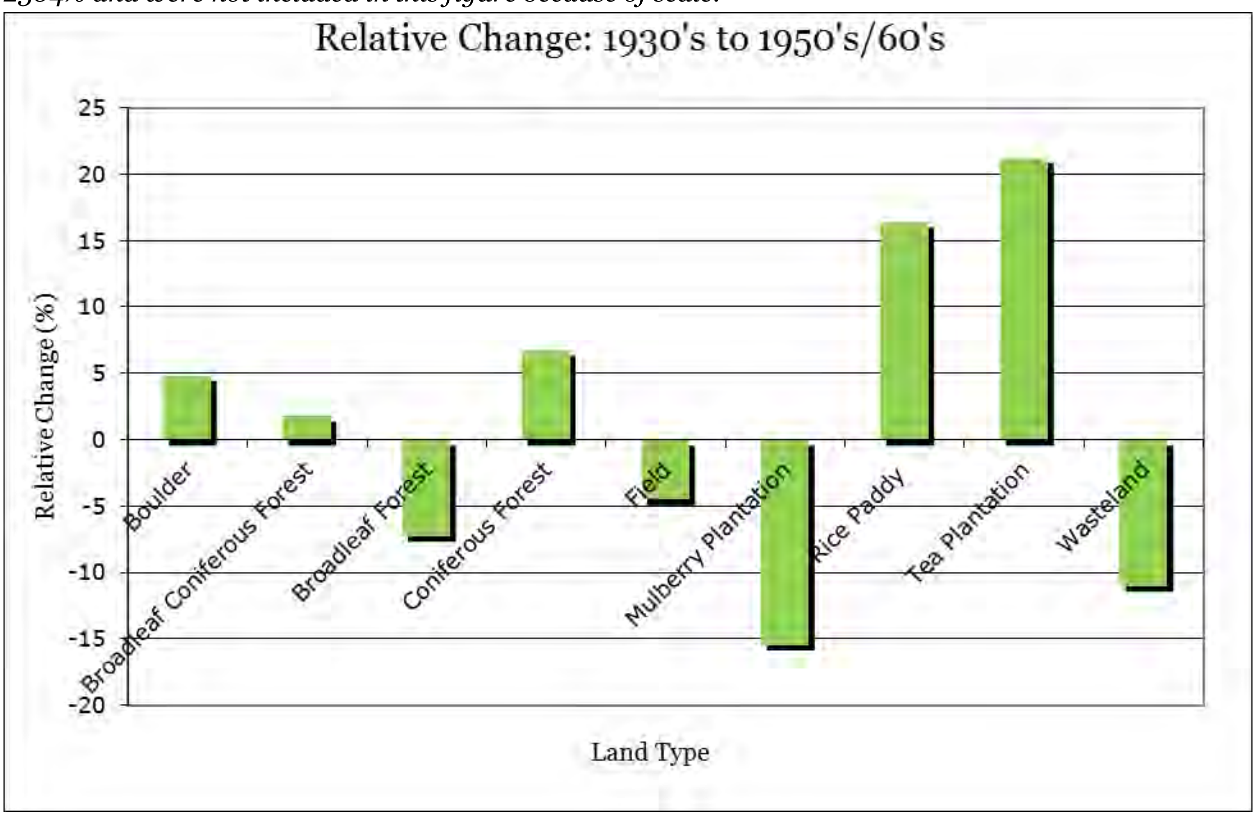

Figure 11. Relative land cover change between 1930 and 19350's/60's.

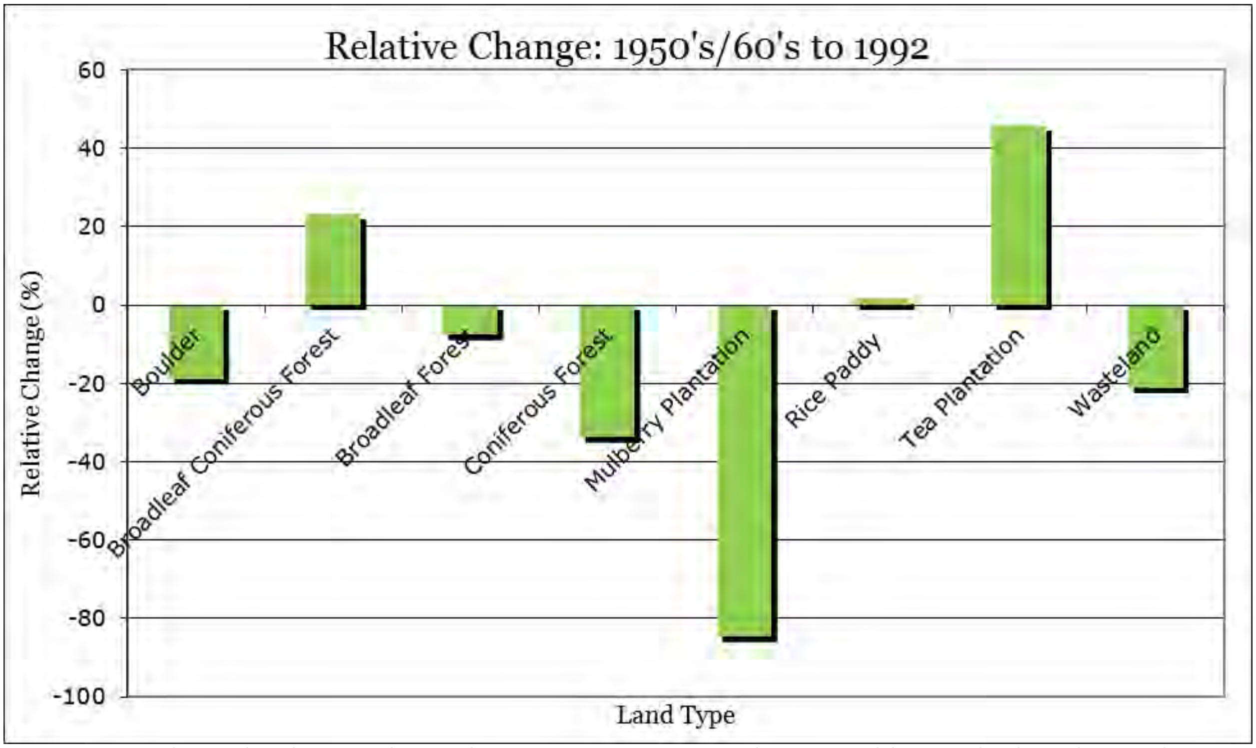

Figure 12. Relative land cover change between 1950's/60's and 1992. Field areas had a relative change of 546% and were not included in this figure because of scale.

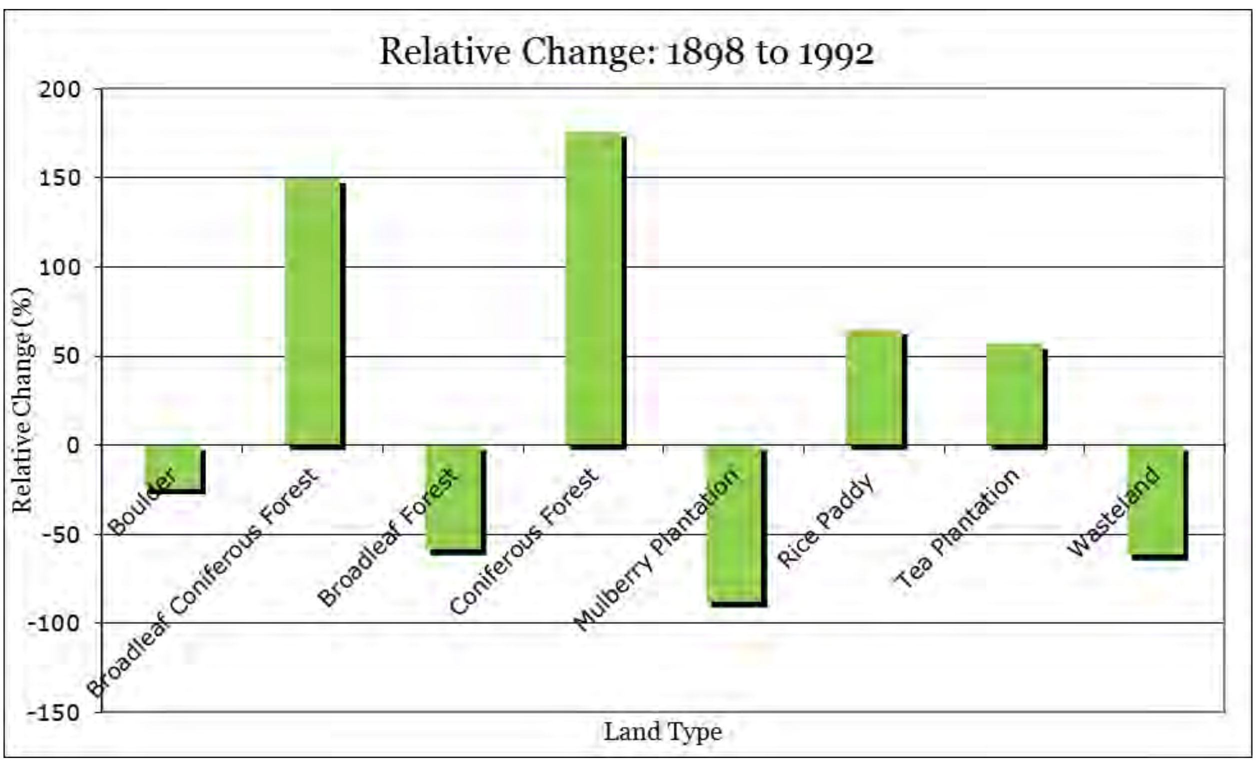

Figure 13. Relative land cover change between 1898 and 1992. Field areas had a relative change of 14, 726% and were not included in this figure because of scale.

Relative land cover change analysis reveals which land cover types expand, emerge or shrink overtime, but it omits information regarding absolute area of change and land cover transitions. To analyze land cover transitions, I wrote a code as follows: each land cover type (C) was given a digit (1-13) and each decade (i_{dec}) was given a power of 10 (1-100000):

$$Transformation\ code = C \times 10^{(idec)}$$

For example, broadleaf coniferous forests were given the value of 2 for 1898, the value of 2000 for 1930, the value of 200,000 for 1950. After assigning values to each land cover type of each decade, land cover rasters were added, resulting in a map of land cover change (figure 5). Cell values of the "sum" raster were codes of land cover change:

$$C_{dec1} \times 10^{(idec1)} + C_{dec2} \times 10^{(idec2)} = \Delta$$

For example, a value of 2013 represents transitions from wasteland (code 13, in 1898) to broadleaf coniferous forest (code 2000, in 1930's). Land cover change patterns were sorted by area. The top 16 transition types by area were used for further analysis (figures 12-16).

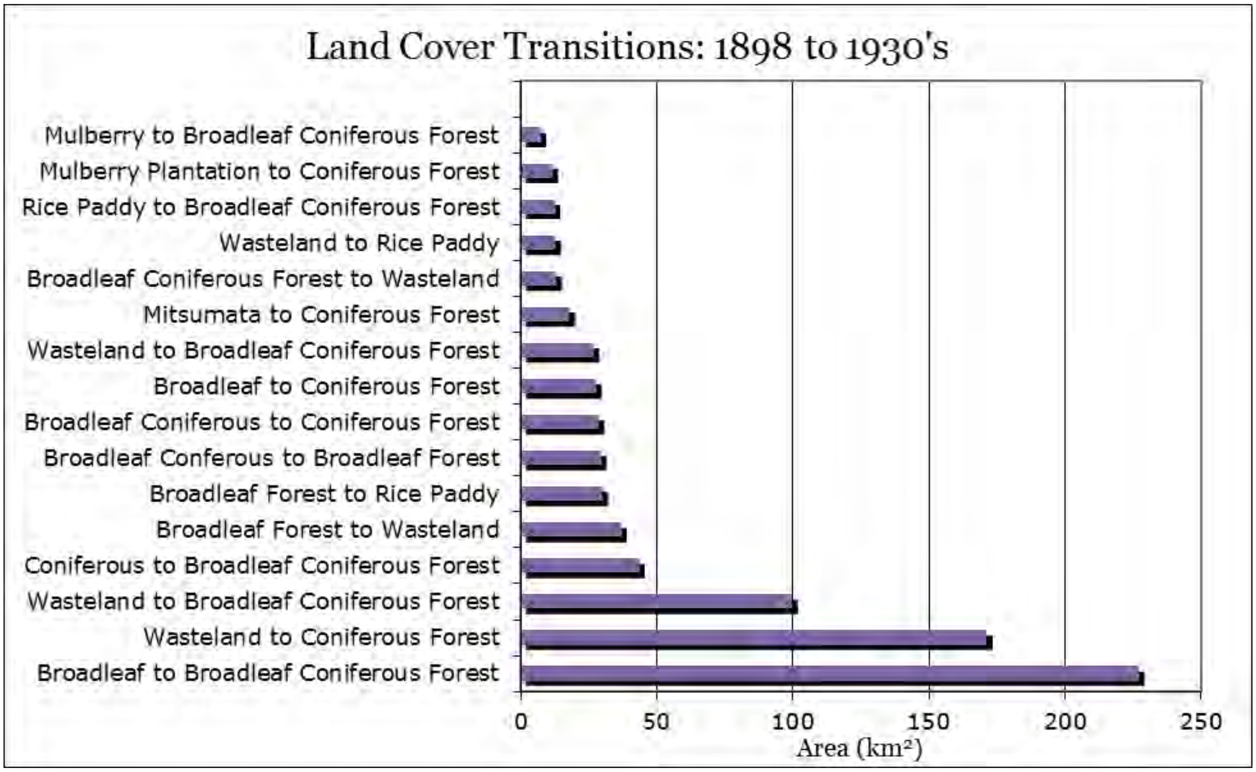

Figure 14. Absolute area of particular land cover transitions between 1898 and the 1930's.

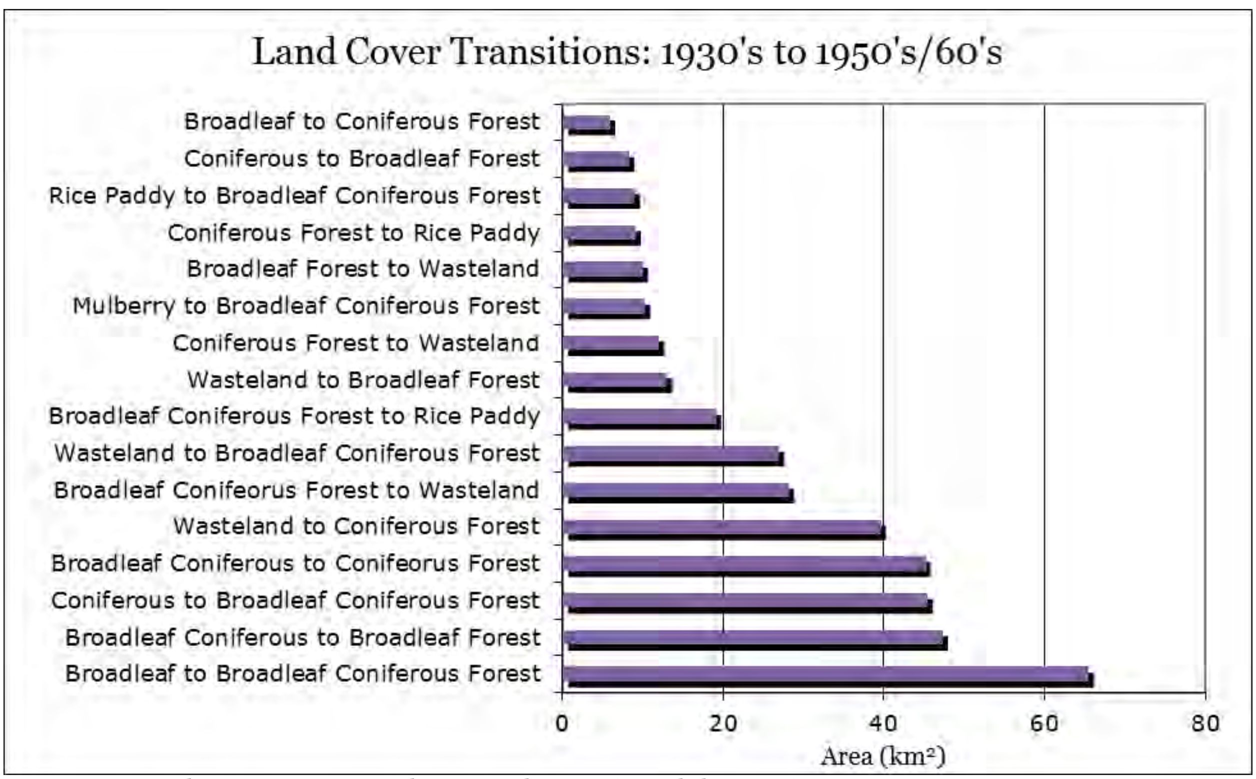

Figure 15. Land cover transitions between the 1930's and the 1950's

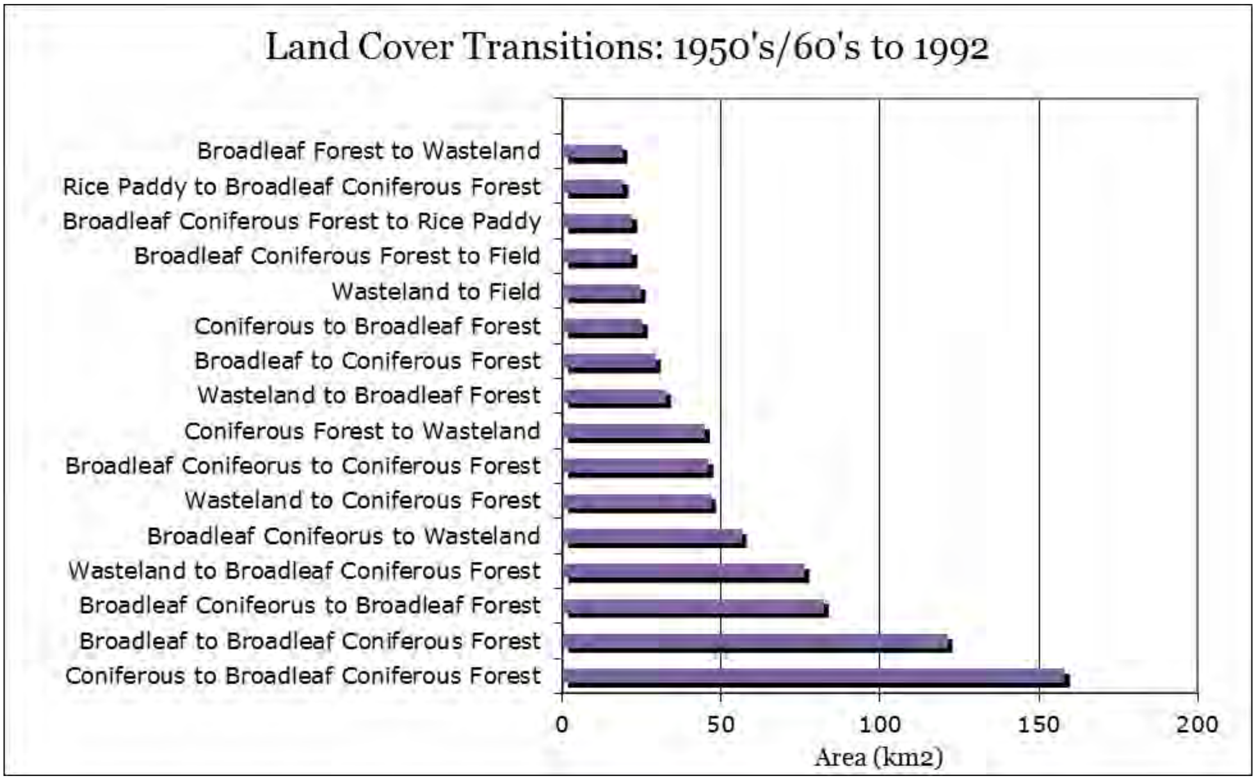

Figure 16. Land cover transitions between the 1950's and 1992

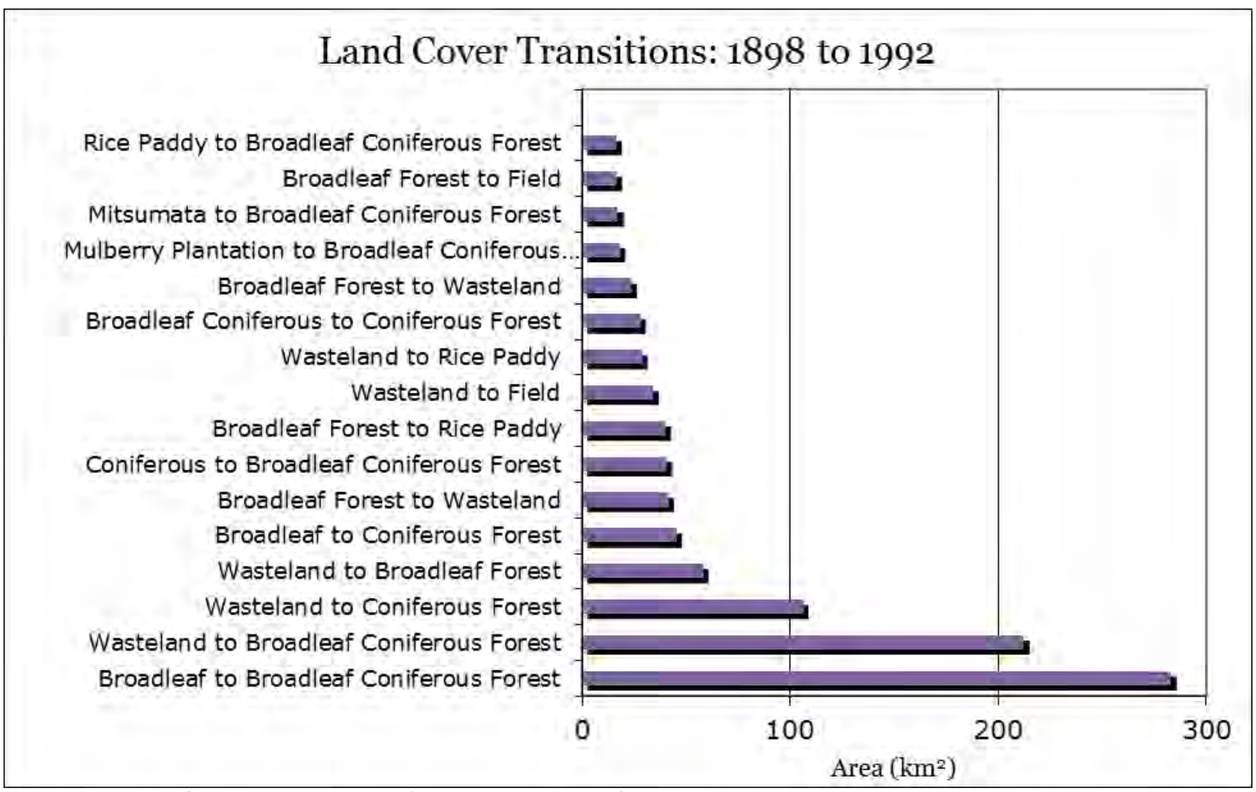

Figure 17. Land cover transitions between 1898 and 1992.

Analysis was done only for areas that transitioned to a completely different land cover type, for every sequence, and disregarded areas of no change (i.e broadleaf coniferous forest to broadleaf coniferous forest).[68]

Over the 20th century, the largest transitions of land cover change were from wasteland and broadleaf forests to broadleaf coniferous, coniferous forests and fields. Broadleaf coniferous forest growth had a steady rate of increase throughout the 20th century, while coniferous forests showed a sharp increase between 1898 and the 1930's. Wasteland areas rapidly declined between 1898 and the 1930's. Mulberry plantations decreased in area between the 1950's/60's and 1992 while field areas had a rapid increase during the same period. Area inhabitated bu Mitsumata, a plant used for traditional Japanese paper production, transitioned to coniferous forests between 1898 and the 1930's. Rice paddy areas increased between the 1898 and 1930's as well as between the 1950's/60's and 1992, but showed very little change between the 1930's and the 1950's/60's. In fact, very little land cover change occurred between the 1930's and the 1950's/60's and 73% of the study area did not change during this period.

Part 2. Geologic constraints on Mt. Fuji

The second portion of my analysis investigates linkages between substrate and land cover. A JPEG of a geologic map of Mt. Fuji from the *Geologic Survey of Japan* was georectified and digitized using ArcMap 10.[69] Substrates were categorized by age and type and were sorted into five age groups and types (young-flows after 2000 years before present, middle-flows during 2,000-4500 years before present, old-flows during 4,500-11,000 years before present, tertiary volcanic rocks and sediments). The geologic map was intersected with the previously analyzed land cover maps on ArcMap 10 (figure 16.) The intersected map provided information about which land cover types were located on which geologic "group."

[68] From 1898 to the 1930's, 792 km^2 were areas of no change; from the 1930's to the 1950's/60's, 1224 km^2 were areas of no change; from 1950's/60's to 1992, 718km^2 were areas of no change and from 1898 to 1992, 495 km^2 were areas of no change.

[69] Tsuya, H. "Geology of Volcano Mt. Fuji. Explanatory text of geologic map 1: 50,000 scale." Geological Survey of Japan, Kawasaki (1968)

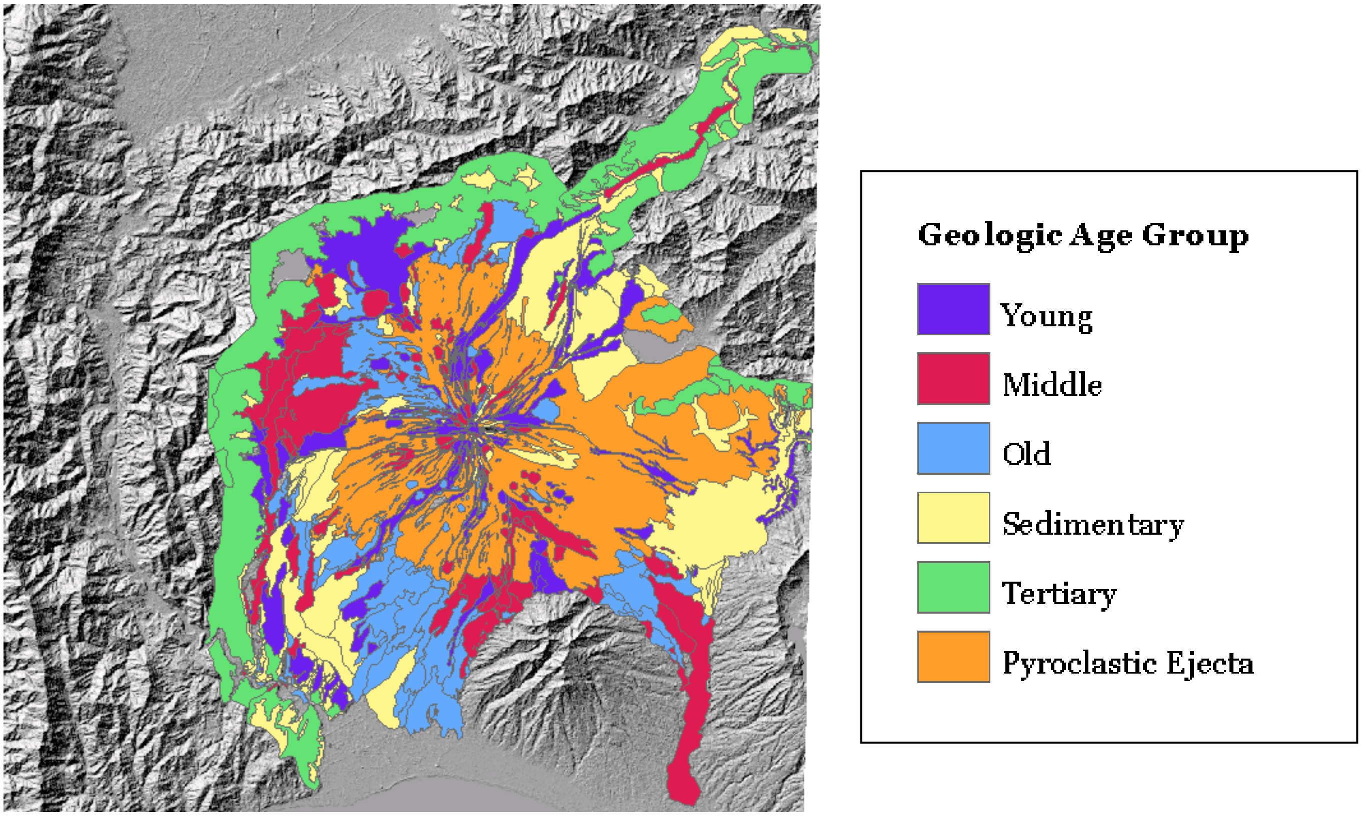

Figure 18. Bedrock geology of Mt. Fuji, categorized based on age and type.

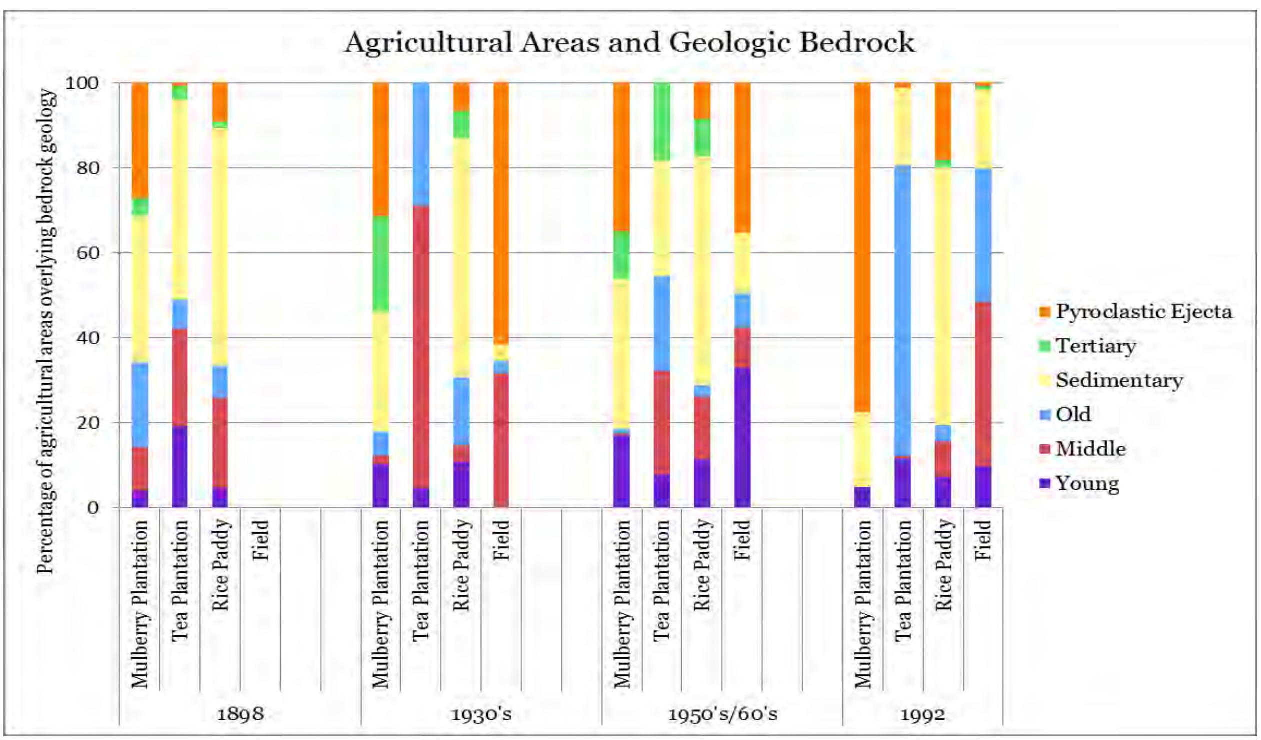

Figure 19. Percentage of agricultural areas in 1898, the 1930's, the 1950'2/60's and 1992 overlying bedrock geology. Field areas were not observed in 1898.

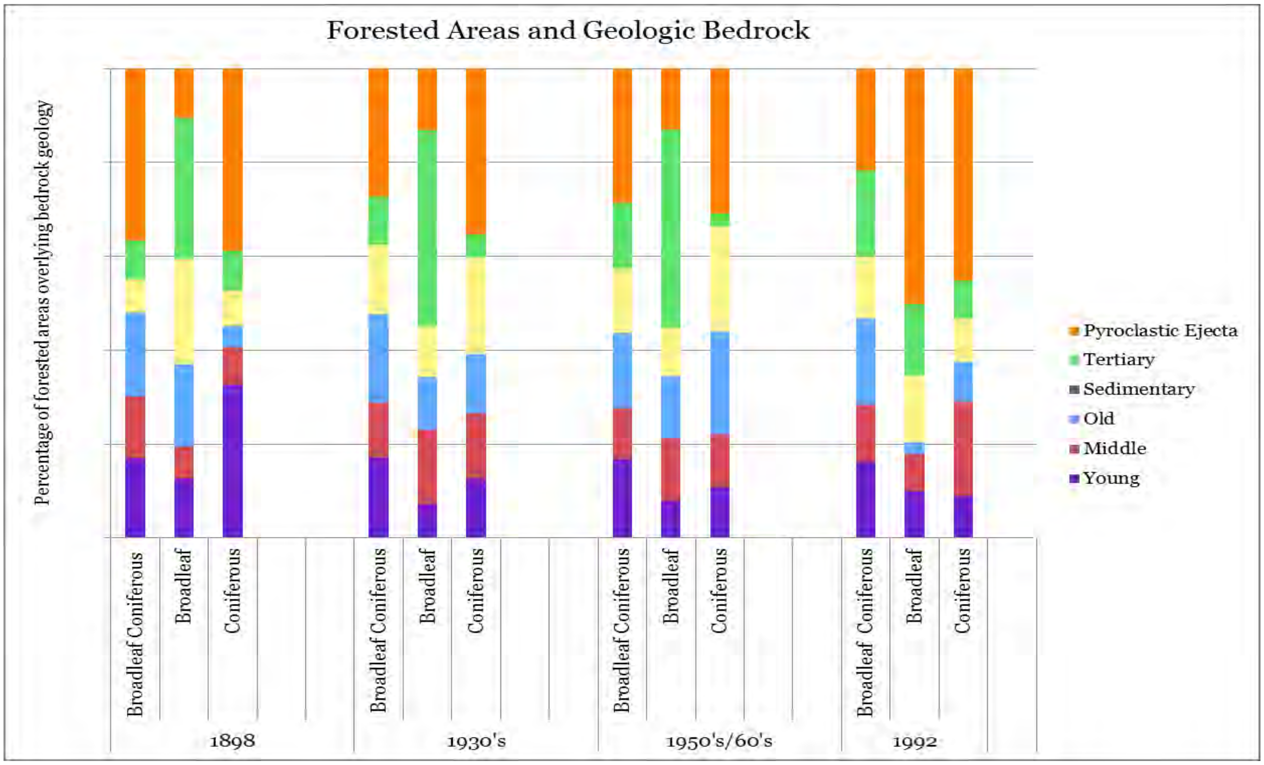

Figure 20. Percentage of forested areas in 1898, the 1930's, the 1950'2/60's and 1992 overlying bed rock geology.

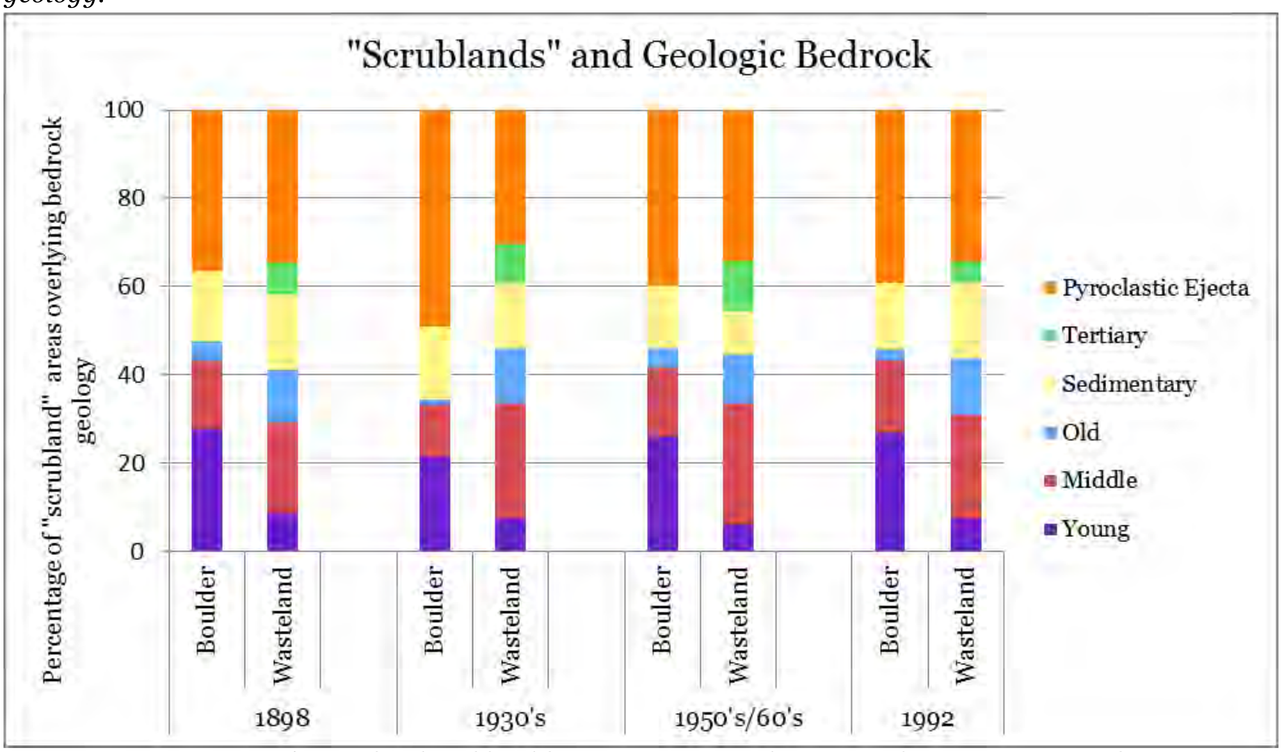

Figure 21. Percentage of wasteland and boulder areas in 1898, the 1930's, the 1950'2/60's and 1992 overlying bedrock geology.

In 1898, 1930's, the 1950's/60's and 1992, forested, boulder and wasteland areas showed very little change in substrate type, located primarily on pyroclastic ejecta. Rice paddy areas were located primarily on old lava flows or sedimentary strata for all analyzed years. Tea plantations were located on old, middle and sedimentary strata. Mulberry plantations were primarily located on sedimentary and pyroclastic ejecta while field areas showed more adaptability, located on sedimentary, young, middle and pyroclastic ejecta strata types. Mulberry and tea plantations may not be the most representative of agricultural geologic limitations because they covered such a small portion of Fuji over every analyzed period.

Forested areas were flexible to bedrock conditions, and were located on all types of volcanic bedrock, including strata with low water retention. While forests and agricultural areas were located on young pyroclastic ejecta (a dominant bedrock type for Fuji), the distance from the summit varied between these two groups. Forested areas were located at high elevations near Fuji's peak while agricultural areas were located on skirt, at lower elevations. Increased distance from the summit often means a thinner layer of pyroclastic ejecta, which reduces soil permeability constraints for agricultural crops. Trees, which have longer root systems, are flexible to thick layers of pyroclastic ejecta. Temperature and precipitation are factors that influence land cover and bed rock weathering at varying elevations.

Of course, there are margins of error in my analysis. Errors may have resulted from incorrectly hand tracing land cover boundaries of the Fuji quadrants and distortion from GIS digitizing and processing. For example, lake area changed from 17.4 km^2 in 1898 to 15.5 km^2 in 1992, an 11% decrease that was likely caused by tracing errors and image distortion. Portions of the Fuji Geologic Map did not intersect perfectly with land cover boundaries. This was a coordinate datum offset which had negligible effects.

Interpreting Land Cover Change Patterns

Cultivated croplands have been located in the few areas with water retention capabilities, while forests and grasslands dominate lands with high soil permeability. In light of these geologic constraints, I will now consider how resilient Mt. Fuji is to shifting patterns in resource demand.

The dominant land cover transitions between 1898 and 1992 were from wasteland and broadleaf forests to coniferous forest or broadleaf coniferous forest. This can be explained by various land use practices and phenomena. The increase of forest cover on Mt. Fuji is a result of regenerative forestry practices, which were developed in the 18th century, and have shaped much of Japan's land cover today.[70]

Prior to and during World War II, clear cutting coniferous forest plantations became the new standard forestry practice.[71] During this period, many previously forested areas in Japan were degraded, and cutting volume exceeded forest growth.[72] For example, in Japan, between 1900 and 1950, broadleaf forest areas decreased by 3720 km^2 and coniferous forests decreased by 330 km^2, although mixed forests increased by 9840 km^2.[73]

Interestingly, Mt. Fuji also experienced a decrease in both broadleaf and coniferous forests prior to World War II, with an increase of mixed forests. These changes occurred primarily at the expense of common grassland areas. Common grassland areas may have been used for timber resource security on the slopes of Mt. Fuji and at the same time, rural depopulation reduced the need for common grassland areas.

In 1951, the Japanese government passed a forestry law that was designed to increase forest protection for land protection and the national economy.[74] This was indicative of both resource security goals and wartime over felling of forests that led to landslides and flooding. Restoration of destroyed cities and economic growth created a demand for timber and an increase in timber prices motivated tree plantation.[75] This explains a 150 km^2 increase of broadleaf-coniferous forest areas (transitioned from wasteland) on Mt. Fuji between 1950's/60's and 1992. Similarly, between the 1950's and 1985, Japan experienced a 43810 km^2 increase of mixed forests but a decline in both coniferous and broad-leafed forests.

During the 1960's rural migrations to urban areas depopulated village communities and decreased the use of common lands (wasteland) and subsistence agriculture/farming.[76] At the same time, the demand for fuel wood decreased rapidly because other sources of imported energy (coal, oil, gas) became available at lower costs and effort. This reduced the need for broad-leafed trees for fuel wood and free up land to be used for managed coniferous plantations, which were used for building materials.[77] Horses and thatch for thatched roofs became obsolete

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[70] Totman, Conrad. "Plantation forestry in early modern Japan: economic aspects of its emergence."
[71] Paletto, Alessandro, Cristina Sereno, and Hiromichi Furuido. "Historical evolution of forest management in Europe and in Japan." (2008)
[72] Ibid.
[73] Himiyama, Yukio. "Land use/cover changes in Japan: from the past to the future." Hydrological Processes 12, no. 13-14 (1998): 1995-2001
[74] Ota, Ikuo. "Forest legislation in a constitutional state: The Japanese example." Working Papers 10/1 International Series 82 (2002):3
[75] Ibid.
[76] Iwai, Yoshiya, ed. Forestry and the forest industry in Japan. UBC Press, 2002.
[77] Ibid.

and reduced the need for common grassland areas. Now these same lands are used either for forestry practices, military training grounds or for recreational purposes (i.e. golf courses).[78]

Mt. Fuji represents a location where "the forest transition" has taken place, reforestation has occurred at a rapid pace, and much of Japan's timber is now supplied by Southeast Asia and Canada. Much of this forest transition has been at the expense of common grasslands (wasteland), a property regime that was common practice in rural Japan.

Over the 20th century, rice paddy areas showed an increase of 81 km^2, predominately at the expense of broadleaf forests and wasteland areas. Rice is the central agricultural crop grown in Japan, and throughout the 20th century, the area devoted to rice production has exceeded the area devoted all other crops combined.[79] Similarly, on Mt. Fuji in 1992, the area devoted to rice was 123.3km^2 while all other agricultural areas composed 84 km^2 , which is consistent with larger scale observations of Japan. Interestingly, between 1900 and 1985, land area used for rice cultivation in Japan increased by 1110km^2, but decreased between 1950 and 1985 by 500km^2.[80] In contrast, rice paddy fields increased on Fuji between 1950 and 1992.

These transitions can be explained by economic mechanisms. Profit from rice plantations has fluctuated over the 20th century (driven by demand, government subsidies, civil engineering practices etc.).[81] In the 1920's and 1930's, rice prices slumped because of limited state funding and a government focus in Korea and Taiwan (the Japanese government promoted rice cultivation in these colonies for cheap food imports).[82]

After World War II, Japan no longer imported rice from the former colonies, and instead the government subsidized rice cultivation for resource security purposes.[83] In the 1950's and 1960's, rising prices and inflation of rice increased production and enabled civil engineering projects that improves irrigation and drainage of paddy fields while simultaneously increasing the area of agricultural land.[84] The 1970's was a period of price stagnation, leading to an oversupply and since the 1990's, prices of rice have fallen sharply, and potential profitability over rice farming operations is questionable.[85]

Mulberry plantations showed a decrease of 28 km^2, transitioning primarily to broadleaf coniferous forests. Similar trends occurred in other areas of Japan and between 1900 and 1985, the total land area in Japan designated to mulberry fields decreased by 1980 km^2. Mulberry

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[78] Bernstein, Andrew. "Guns and Grass: The Militarization of Fuji's Common Lands." International Association for the Study of the Commons (2013).
[79] Waswo, Ann, and Yoshiaki Nishida, eds. *Farmers and Village Life in 20th Century Japan*. Psychology Press, 2003.
[80] Himiyama, Yukio. "Land use/cover changes in Japan: from the past to the future."
[81] Ibid.
[82] Ibid.
[83] Barker, Randolph, Robert W. Herdt, and Beth Rose. *The rice economy of Asia*. Vol. 2. Int. Rice Res. Inst., 1985
[84] Waswo, Ann, and Yoshiaki Nishida, eds. *Farmers and Village Life in 20th Century Japan*.
[85] Ibid.

plantations are used for the cultivation of silk worms, which produce silk and are located in mountainous prefectures, and confined to low slopes.[86] During the 1870's, raw silk and cocoons comprised nearly 39% of Japan's exports and tea comprised 25%.[87] Compared to world prices, Japanese prices were 33% higher. Coupled with high quality and increased demand, these commodities composed nearly two-thirds of Japan's exports by value.[88] Until the 1960's, Japan was named the world's top producer of silk and has been rapidly declining since the 1970's.[89] Driven by a reduced global demand for silk, the decline of Japanese silk production parallels the reduction of mulberry plantations on Mt. Fuji.

Between 1898 and 1992, tea plantations increased by 5km^2 on Mt. Fuji. This is not unlike a trend found in Japan, where tea fields increased from 170 km^2 to 500 km^2 between 1900 and 1985.[90] Tea was the second largest commodity export (behind silk) in Japan near the end of the 19th century.[91] Prior to World War II, tea exports slowed and following the war, the government attempted to promote tea as a major export commodity but it was not priced competitively.[92] By 1971, Japanese tea exports rapidly declined, but domestic consumption increased.[93]

Field areas increased by 66 km^2, at the expense of wasteland and broadleaf forests, for the same reasons listed from above, the need for common grassland areas declined and cultivated plots of dry fields used for cereal and vegetable crops increased.

Around Mt. Fuji, sedimentary deposits, which are the most suitable for cultivation because of their reduced permeability, are relatively sparse. Both rice plantations and tea plantations were located on sedimentary (i.e terraces, lahar deposits, alluvium deposits) and "old" geologic strata types, layers, similar to sedimentary, that have fairly high water retention properties because they have had time to weather and break down into smaller grains. Scrublands, broadleaf, broadleaf coniferous and coniferous forest types were located primarily on pyroclastic ejecta. Young volcanic bedrock rarely has surface streams because rainwater and melt water usually pass through loose scorious substratum, leaving little available water for growth.[94] Wooded vegetation has lower water requirements compared to plants with shallower root systems and agricultural varieties such as rice paddy plantations, which require large

86 Datta, Rajat K., and Mahesh Nanavaty. *Global silk industry: a complete source book*. Universal-Publishers, 2005
87 Huber, J. Richard. "Effect on prices of Japan's entry into world commerce after 1858." *The Journal of Political Economy* (1971): 614-628.
88 Ibid.
89 Datta, Rajat K., and Mahesh Nanavaty. *Global silk industry: a complete source book*.
90 Himiyama, Yukio. "Land use/cover changes in Japan: from the past to the future."
91 Yasuba, Yasukichi. "Did Japan Ever Suffer from a Shortage of Natural Resources Before World War II?." The Journal of Economic History 56, no. 03 (1996): 543-560
92 Tanaka, Junichi. "Japanese tea breeding history and the future perspective." In Global Tea Breeding, pp. 227-239. Springer Berlin Heidelberg, 2012.
93 Ibid.
94 Ohsawa, Masahiko. "Differentiation of vegetation zones and species strategies in the subalpine region of Mt. Fuji." Vegetatio 57, no. 1 (1984): 15-52.

amounts of irrigation to grow.[95] Elevation and slope limit land cover to forests and boulder in the alpine and subalpine region of Fuji.

Forestry Abandonment

Managed forest plantations have decreased in use and value. This has primarily been driven by low prices of imported wood from Southeast Asia that was cheaper than Japan's rather high costs.[96] Japan's costs were high due to the difficulty in cutting because of steep mountainous slopes and due to rising wages of forest workers. At the same time, timber prices began to decrease, rapidly reducing the profitability of extracting timber from mountainous areas in Japan, including Fuji.[97]

Today, there remains little use for the timber plantations in Japan, besides providing hill slope stability and erosion control. While in pre-war and wartime eras, over-felling led to resource scarcity and flooding, over-forestation has become a large issue for upland villages and communities.[98] Tree monocultures and plantation forests should be managed, pruned and protected. Recently, many of these forests have begun to deteriorate because there is no longer an economic incentive to manage, prune and maintain these stands. Abandoned plantations, often vine covered have reduced market value leaving them economically worthless.

This land cover pattern mirrors the abandonment of croplands, in which socio-economic factors such as immigration to areas with increased economic incentives lead rural inhabitants to abandon cultivated areas (trends which have been observed in Puerto Rico, Spain and southeast Poland).[99] Often, these lands exhibit low biodiversity, increased soil erosion, and decreased cultural and aesthetic value. Prescribed solutions to cropland abandonment have been to reward those that maintain agricultural cultivation and to revitalize abandoned land through rural tourism. These solutions have been investigated in studies pertaining to forestry in Japan.[100]

Through a series of forestry transitions, Japan has arguably become "stuck," no longer utilizing locally managed forestry resources and lacking economic incentives to maintain or

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95 Smathers, Garrett A., and Dieter Mueller-Dombois. "Invasion and recovery of vegetation after a volcanic eruption in Hawaii." (1972).
96 Knight, John. "A tale of two forests: reforestation discourse in Japan and beyond." Journal of the Royal Anthropological Institute (1997): 711-730.
97 Iwai, Yoshiya, ed. Forestry and the forest industry in Japan.
98
99 Benayas, JM Rey, Ana Martins, Jose M. Nicolau, and Jennifer J. Schulz. "Abandonment of agricultural land: an overview of drivers and consequences."
100 Knight, John. "From timber to tourism: recommoditizing the Japanese forest." Development and Change 31, no. 1 (2000): 341-359.

transform these over-grown forests into other land cover types. Geologic constraints exacerbate this problem, because land management is limited to vegetation that can persist in areas of low water retention and can colonize young volcanic bedrock.

Terrestrial Limitations and Economic Vulnerability

Mt. Fuji is not the only place with land use constrained by young volcanic bedrock. Much of the Oregon High Cascade Range is composed of young, porous basaltic lava flows with low water retention capabilities and this region has limited vegetation establishment.[101] Areas where glaciers have deposited finer grains and locations with older, weathered bedrock have a lower permeability and lateral drainage flow.[102] These finer sediments are more conducive to vegetation than young, permeable surfaces. Regardless, these landscapes are dominated by Douglas fir and other forest species rather than by agricultural cropland.[103]

Constraints such as these, coupled with economic changes and political shifts can lead to a devaluation and abandonment of rural areas. These forces often lead to dead ends in which flexible land uses are no longer profitable and very few land use substitutes can take place. Economic opportunities are not solely limited by geologic constraints, but by climate, topography and land degradation. For example, in arid and semi-arid regions productivity loss caused by land degradation and lack of economic incentives has led to rangeland abandonment.[104] Severely degraded rangelands may not return to their previous state. Just as economic processes have led to stymied land alternatives, ecological degradation coupled with socioeconomic factors have left these landscapes monetarily worthless.

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[101] Jefferson, Anne, G. E. Grant, S. L. Lewis, and S. T. Lancaster. "Coevolution of hydrology and topography on a basalt landscape in the Oregon Cascade Range, USA." Earth Surface Processes and Landforms 35, no. 7 (2010): 803-816

[102] Ibid.

[103] Ibid.

[104] Milton, Suzanne J., W. Richard J. Dean, Morné A. du Plessis, and W. Roy Siegfried. "A conceptual model of arid rangeland degradation." Bioscience (1994): 70-76

Future of Fuji

Although the most flexible and generic land uses have become the least valuable, they may have opportunities too. With overgrown plantation forestry and limited land cover alternatives, a rapid increase of tourism can lead to land cover transitions that are more visitor friendly, and consequently, more profitable. National policies can further these transformations, subsidizing particular land cover changes and rewarding forestry and national park employees. Established as a National Park in 1931, Fuji attracts 300,000 climbers a year and in 2013, Mt. Fuji was officially registered as UNESCO World Heritage site. Japan has 28 national parks, most of which include mountainous areas. These national parks have contributed to recent increases in domestic and foreign tourism. In 2011, tourism contributed to 6.8 percent of Japan's GDP (approximately $376.55 billion).

Similarly, in 2010, Hawaii received $10.931 billion from tourism expenditures, which composes nearly 11.4 percent of Hawaii's GDP. Hawaii, similarly to Japan, is a small volcanic region with little agricultural export opportunities because of a geologically constrained landscape. Geologically limited areas are not without monetary value in Japan and elsewhere, but infrastructure, terrain and foreign demand may constrain profit. Unlike semi-arid regions with abandoned rangeland, both Japan and Hawaii are popular destinations. Japan and Fuji in particular, is filled with historical, cultural and aesthetic value that pave new pathways for land use.

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