

LAND USE CHANGES DURING THE PAST 300 YEARS

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Keywords: historical land use, land cover, forest, deforestation, conversion, agriculture, cultivation, pasture, rangeland, urbanization, built-up land

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Summary

The human sphere of influence on world's natural environment has increased during the last 300 years at a staggering rate. Dramatic increases in population numbers boosted the need for food and fodder production. Land used for crops and ranching expanded at the cost of forests and natural grasslands. Estimates for the decrease in global forested area during the last 300 years range from 8 to 13 million km², corresponding with 15 to 25 % of the original extent in 1700. A great part of the large uncertainty in this estimate (and others given in this whole section on historical land use) can be explained by the use of different classification schemes of the historical inventories (forest or woodland, tundra or wooded tundra, grassland versus savanna, etc.). Other reasons are the different methodological approaches used (interpolations, proxies used for filling in the gaps) and the absence of present day technology like satellite derived data. Approximately 15 to 19 million km² of natural grassland and savannas were also domesticated in one way or

another. It is generally accepted that these land use changes have contributed to an increasing extent the enhancement of the so-called global greenhouse effect. Estimates of the IPCC stated that roughly one fifth of the total anthropogenic emissions of greenhouse gases during the 1990s originated from changes in land use.

Land use change does not occur evenly, neither temporarily nor spatially. In fact, it has become clear that in some parts of the world, the process of massive conversion of natural land cover has stopped, or has even been reversed, the so-called “forest transition”. This transition is marked by a first gradual or sudden depletion of the forest resources, later by slow or radical changes in economic structures or organization. These lead to a new appreciation of the resources and eventually in an increase in forest area again. This process is currently happening in North America, Japan, and some European countries. It seems to be a first step towards a more sustainable world.

1. Introduction

Since the dawn of civilization, humans have altered the face of the Earth while acquiring valuable resources such as food, fiber, and fresh water. Human alterations of the landscape and their deleterious consequences have been noted for a long time. Greek philosophers like Plato or Aristotle, and Roman Emperors such as Hadrian have already reported about the deterioration of natural vegetation and the erosion of fertile land. George Perkins Marsh’s book “Man and Nature”, written in 1864, was one of the first widespread manuscripts to recognize mankind’s harmful effect on nature. Since then, various writers such as Henry David Thoreau, John Muir, Aldo Leopold, and Rachel Carson have contributed to the rise of consciousness about environmental issues. More recent publications, like “The Earth as Transformed by Human Action” by Turner et al., and voluminous integrative reports of the IPCC, UNEP and WRI document some of the historical changes in land use and land cover due to human action over the last decades to centuries.

More recently, tropical deforestation has drawn attention to human impacts on the environment. The loss of pristine tropical rainforests in the Amazon basin, and the associated loss of biodiversity and accelerated extinction of species have captured the global imagination. According to the Forest Resources Assessment 2000 of the FAO, the current loss of forest amounts to roughly 0.146 million km² per year. Since pre-agricultural times, several estimates indicate that the loss of forests ranges between 11 and 17 million km², which corresponds roughly to the size of the continental U.S.

There have been surprisingly few global-scale estimates of the changes in land use and land cover. Estimates range from a reduction of 15% to 30% of the total forest area since pre-agricultural times, and roughly half of the land surface (three-quarters of the habitable area) has been disturbed in some way or another by human beings. Richards (1990) summarized different calculations to estimate that over the last 300 years, we have lost roughly 20% of our forests and woodlands, 1% of grasslands and pastures (most pastures came from grasslands), while cropland areas increased by 466%! Currently, croplands occupy roughly 15 million km² of the Earth’s surface, which corresponds to an area roughly the size of South America, while grazing lands cover approximately 34 million km². Thus, more than one-third of the global land surface is

devoted to agricultural land, which has now become one of the largest biomes on the planet, for example roughly equal to the global extent of forests.

Such large-scale changes in land use and land cover can have significant consequences such as the depletion of valuable ecosystem goods and services. For example, forests are the source of fiber and valuable pharmaceutical products, and provide important services such as the regulation of climate and surface water, and protection of the soil. Furthermore, tropical rainforests provide a valuable habitat for an enormous number of plants and animals on this planet.

The changes in land use and land cover have accelerated over the last three centuries, since the onset of the Industrial Revolution. Land use is one of the most obvious and major drivers of global change. With this recognition, there have been an increased number of studies of the causes and consequences of land use and land cover change. In this paper a summary is given on the current understanding of historical changes in land use and land cover.

2. Terminology

Before launching into a discussion of the historical changes in land use and land cover, some clarification on terminology is needed. Land use refers to the purpose or intent for which a piece of real estate is being used. Land cover refers to the perceivable alteration of the land surface. Cultivation, grazing, ranching and urbanization, are all examples of land use activities, while cropland, pasture, rangeland, built-up land, and so on are all examples of land cover. Generally, the management of land, including tilling, fertilization, and irrigation, is also characterized as land use activities.

Furthermore, a distinction is often made between land cover *modification* and *conversion*, although this is generally a matter of scale of observation. A land use activity usually modifies the land cover only. For example, firewood gathering or selective logging will usually leave a forest behind, only degrading it or modifying it. On the other hand, clear-cut logging or the clearing of a forest for cultivation will convert the woodland into bare ground or cropland. Land cover conversions are much more obvious than land cover modifications.

3. Human Activities on the Land in Pre-industrial Times

The earliest influence of humans on their natural environment started with the domestication of fire. It helped to open up natural savannas and grasslands for hunting and early forms of agriculture. Gradually, over millions of years humans learned not only to use tools, but to make them as well. This phase is also known as agrarization. Being able to control the important factors of fire and tools, it enabled groups of people to leave their original habitat, the savannas of Africa and migrate to other parts of the world. They spread out towards remote corners of Eurasia (Euphrates and Tigris region), and later on to areas like the Indus valley in northern India, and eventually to the America's and Australia. The humanoids evolved towards a more sedentary existence and adapted new crops and some domestication of animals as well. This has lead to an increasing population over time, albeit a very modest increase over thousands

of years.

Most, if not all, of the early forms of agriculture developed in the hills and valleys around the large mountain ridges. Examples of these are the Iranian Plateau and its edges with traces of farming ca. 6000-12000 yr BP, and the hilly regions in northern China and Central America. This transition from (mobile) hunting/gathering to (sedentary) farming is often referred to as the “Neolithic Revolution”. Europe was another relatively favorable region for early human settlement. The continent has lots of shorelines for fishing, a relative temperate climate combined with numerous fertile river valleys that are quite suitable for agriculture, vast areas of open grassland plains for nomadic herd rearing, and above all plenty of forest/woodland to provide fuel, fodder and shelter. Archeological evidence along with pollen analyses shows that even in those early days the influence of humans on the surrounding woodlands in Europe and the Mediterranean was not negligible. Humans have been sailing from Central Asia into the Mediterranean Basin since early 4000 BP, spreading their agricultural practices and thus influencing their natural environments.

The (Pre-) Greek Era - In 6000 BP, the Southern Argolid, the Argive Plain and the Larissa Basin of Greece show clear signs of early agriculture. Rainless winters, frost and wind erosion led earliest settlers to adopt subsistence strategies such as risk avoiding through a mixed-cropping or sheep holding as low-risk meat providers. Archaeological and paleological evidences suggest that their grazing and farming activities on the valley slopes already resulted in catastrophic erosion. Aristotle claimed in 2500 BP that the land had undergone considerable alteration, and Plato described the permanent damage to the environment, probably resulting from overexploitation of primary forestland. The local forests in Greece were denuded, and as a result, the Athenians had to import an extensive amount of timber, most notably from Phoenicia. It is this wood that contributed to the development of the great Athenian fleet of ships.

The deforestation of the Levant region (currently Lebanon) is a good example on how human activities of different kinds have affected the land cover in this area. By the seventh century BC Levantine iron was being exported to Babylon. Iron oxides occur locally in the Lebanon mountains and were amongst the first iron ores ever to be exploited. Unfortunately, iron smelting requires high temperatures and, therefore, was a major factor in the deforestation. The limestone has also been used, both as a building stone and as fertilizer and cement; and the treatment of those products also use a lot of wood. The results of the commercial interests of the Phoenicians and sea-faring exploits had a special impact on the timbered areas of Lebanon, as near-total denudation took place.

Of an almost equal importance were the effects of military campaigns and the commercial demands on wood. Along coastal strips and lowlands of the Mediterranean, the primary areas of settlement, forested land was rapidly cleared. As a consequence, a lumber trade developed between forested regions and sparsely-timbered or deforested regions around the Mediterranean. For nearly three millennia (c. 2600 BC - 138 AD), the timber from the mountains of Lebanon served obvious needs of early settlement, demand for fuel, ship and other building material, as well as timber for cabinets inclusive. Due to their geographic location close to the sea, the Phoenician cities like

Byblos and Sidon acted as ports for trade, wherein cedar logs from the outlying mountains were felled and transported. The destinations were, in these cases, often-populous coastal lowland nations, for example Egypt and Palestine, which had little timber and yet had a high demand for building materials.

The Roman Era - In classical Rome, forests were the source of fuel, building and war material. Forests had also to be cleared before agriculture could be practiced. Deforestation started around the city (states) and spread throughout the Greek colonies, in Africa or other Roman provinces. In the absence of coal and oil, forests were the main fuel for domestic and industrial purposes (more than 90% of the total wood demand was used for fuel), mostly in the form of charcoal. Charcoal has the advantage of being more easily transported, thus given way to exploit more distant forests instead of nearby town/village forests, who were over-exploited quite soon when population numbers increased in the towns.

The fate of the forest cover depended on a combination of climate, location and control, viz. demands for agricultural land and forest products. The drier climate in the eastern Mediterranean resulted in sparse forests, and in combination with the shallow limestone soils produced much less resilient forests than in the wetter (often mountainous) parts. After exhaustion of forests in the vicinity of villages, people turned to nearby rivers and seaports as means of transport for wood products from more distant forests. Inaccessible forested mountain areas were likely to remain intact.

China - A comparison between Europe and China is very difficult to make, because of the lack of information from the Asian part before the beginning of the Ming dynasty (AD 1368). There is some written evidence of the flourishing iron and steel industry in the Shantung region in northeast China during the Northern Sung period (AD 910 and AD 1126). The substitution of coal for charcoal suggests not only a precocious technological development, but also a widespread devastation and shortage of fuel. Production numbers of charcoal at the end of the Sung period are comparable to the total West European production (including the European Russian part!) at the beginning of the eighteenth century. By the year 1300, the Sung production had declined by half, whether through exhaustion of fuel, Mongol invasions or other unknown factors.

Central America – The human impact on the forests in Central America was already very evident before the Europeans arrived. Indigenous people have been using the forest already for centuries for hunting, the collection of medicinal products, building materials, as well for small-scale agriculture. It resembled the shifting cultivation of the tropical forest of today. In the southeast of Mexico, Mayan exploitation of tropical fruits increased the extension of useful tree species. Besides, original forestland was cleared for a limited agriculture and fuel needs. When the first Europeans arrived, relatively important sections of forestland had already been changed to a more open, park-like vegetation, and the original forest composition had well been altered in some areas.

The Middle Ages - Catastrophic events like the outbreak of epidemic diseases, a deteriorating climate (Little Ice Ages), and economic recessions (due to war) had an opposite effect on forests in Europe during the Middle Ages. Population fell back in numbers in some areas with a staggering 30% due to the Black Plague. This lessened

the pressure on the forests in the neighborhood of cities and villages. Also, other areas which were occasionally used for grazing like swamps and marshes were regarded as “evil” places and left aside. Nevertheless, even in the Middle Ages forest exploitation was already highly-planned and regulated in Europe. Certain trees were favored (Oaks were sometimes not used for wood but for acorns as food for pigs) and over-exploitation was avoided as much as possible, by means of controlled grazing and/or with strict laws. Despite or perhaps thanks to the selection of and preference for certain species and the introduction of exotic species the composition of forests changed gradually over time, in many cases even irreversible. This, in combination with over-exploitation could not be avoided and took their toll. The result was a decrease of total forest areas especially in poor soils.

4. Land Use and Land Cover Changes since the Industrial Revolution

Changes in land use and land cover accelerated over the last 3 centuries, largely driven by technological changes associated with the Industrial Revolution. It is estimated that more forests were cleared between 1950 and 1980 than in the early eighteenth and nineteenth centuries combined. While the forest cover decreased by 20% since 1700, cropland areas quintupled!

| | Forest/ Woodland | Steppe/ Savanna/ Grassland | Shrubland | Tundra/ Hot Desert/ Ice Desert | Cropland | Pasture | Total |
|---|---------------------|----------------------------------|-----------|--------------------------------------|----------|---------|-------|
| <i>Matthews [1983]</i> | | | | | | | |
| Pre-agricultural | 61.5 | 33.9 | 13.0 | 23.1 | 0.9 | - | 132.4 |
| 1980 | 52.4 | 27.4 | 12.1 | 22.9 | 17.6 | - | 132.4 |
| <i>Richards [1990], after the original work of Houghton et al. [1983]^b</i> | | | | | | | |
| 1700 | 62.2 | 68.6 | - | - | 2.7 | - | 133.4 |
| 1850 | 59.7 | 68.4 | - | - | 5.4 | - | 133.4 |
| 1980 | 50.5 | 67.9 | - | - | 15.0 | - | 133.4 |
| <i>Williams [1990]</i> | | | | | | | |
| 1860 | - | - | - | - | 5.7 | - | - |
| 1978 | - | - | - | - | 14.2 | - | - |
| <i>Klein Goldewijk [1997], after Richards [1990]</i> | | | | | | | |
| 1700 | 62.2 | 63.3 | - | - | 2.7 | 5.3 | 133.4 |
| 1850 | 59.7 | 60.6 | - | - | 5.4 | 7.8 | 133.4 |
| 1980 | 50.5 | 34.5 | - | - | 15.0 | 33.4 | 133.4 |
| <i>Ramankutty and Foley [1999]</i> | | | | | | | |
| Undisturbed | 55.3 | 33.4 | 17.9 | 23.6 | 0.0 | - | 130.1 |
| 1700 | 52.8 | 32.3 | 17.4 | 23.5 | 4.0 | - | 130.1 |
| 1850 | 49.9 | 31.4 | 17.1 | 23.5 | 8.2 | - | 130.1 |
| 1992 | 43.9 | 26.7 | 15.9 | 23.3 | 20.3 | - | 130.1 |
| <i>Klein Goldewijk [2001]</i> | | | | | | | |
| Undisturbed | 58.6 | 34.3 | 9.8 | 31.4 | 0.0 | 0.0 | 134.1 |

| | | | | | | | |
|------|------|------|-----|------|------|------|-------|
| 1700 | 54.4 | 32.1 | 8.7 | 31.1 | 2.7 | 5.2 | 134.1 |
| 1850 | 50.0 | 28.7 | 6.8 | 30.4 | 5.4 | 12.8 | 134.1 |
| 1990 | 41.5 | 17.5 | 2.5 | 26.9 | 14.7 | 31.0 | 134.1 |

^a Estimates are given in million km². Note that the amount of pasture after 1970 does not correspond completely with the statistical input. This is due to the allocation scheme. Because the initial land cover map was calibrated for the IMAGE toward 1970 the amount of pasture after 1970 exceeds for some countries the area in which it can be allocated resulting in some areas holding a fraction of pasture which can not be allocated (10% of world total in 1990 mostly in the United States, Eastern Africa, Middle East and Southeast Asia).

^b Pasture is here included in the Savanna/Grassland category.

Table 1: Comparison of Land Use Changes to Other Estimates in Absolute Terms
Worldwide, the patterns of land use and land cover change followed the patterns of European settlement and economic development. In 1700, most of the land use activities were confined to the Old World. This changed since the great discoveries, in particular the discovery of the Americas.

In the New World the landscape modifications and conversions by the native people were relatively limited and for sure not at the scale practiced by European occupants with their modern technologies. With European settlement, intensified land use activities rapidly spread through the Americas. During the nineteenth century and early twentieth century, nations such as the United States, Canada, Argentina, the Former Soviet Union, and Australia developed at the expense of their natural vegetation cover. Land use activities have over the last 50 years slowed down in these countries.

In the developing nations, land use activities accelerated mainly during the twentieth century, and continue today. These countries are trying to expand their agricultural production, and as a result, are depleting their natural resource base.

In Europe, most countries have continued to expand and intensify their land use activities over the last 300 years. However, many of these activities have stabilized as well.

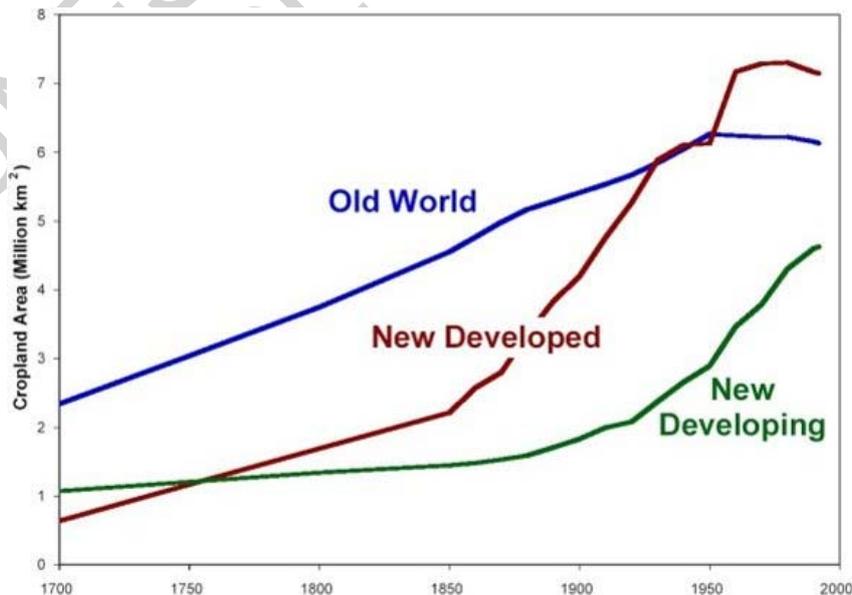


Figure 1: Increase cropland developed/developing world.

The major pattern of land cover change over the last three centuries has been deforestation and agricultural expansion. However, changes in land use practices such as agricultural land management, fire suppression, and urbanization have also been significant drivers of global change. In this section, the various sources of contemporary and historical land use data are first discussed, and then the changes in land use over the last 300 years. The discussion will be mainly on agricultural expansion because it has been the major driver, and also because more is known about it.

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Biographical Sketches

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database is a compilation of historical time series and geo-referenced data on several land use, population, and economic indicators for the last 300 years and may serve as input for integrated models of global change.

Navin Ramankutty is a research scientist at the University of Wisconsin-Madison. His major research interest is in mapping contemporary and historical land use and land cover change, and evaluating the consequences for ecosystem services. In particular, he uses a combination of numerical models, and satellite- and census-based land use data sets, to evaluate the impacts on the global cycles of carbon and water.

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