Global Land-Use Analysis

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Analysis of Global Land Use

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Abbreviations

Fig	Figure
bbl	Barrel
GDP	Gross Domestic Product
CO_2	Carbon dioxide
ibid	*ibidem*
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FRA	Global Forest Resources Assessment
GLCF	Global Land Cover Facility
ha	Hectare
HDP	Human Dimensions of Global Environmental Change Programme
IGBP	International Geosphere-Biosphere Programme
km^2	Square kilometre
l	Litre
lb	American pound (weight)
lbs	American pounds (plural of above)
LCI	Land Cover Institute
LUCC	Land-Use/Cover Change Project des IGBP
LULUCF	UN Land Use, Land-Use Change and Forestry
m	million
million square meters	million square kilometres
mm	millimetre
bn	billion
NASA	National Aeronautics and Space Administration
NASA-LCLUC	Land-Cover and Land use Change Programme NASA
SEEA	System of Environmental-Economic Accounts
t	tonne
USA	United States of America
USGS	United States Geological Surveys
eg	*exempli gracia* (for example)
°	degree
%	percent

1 Analysis of Global Land use, Working Package 1.1

1.1 Introduction

The aim of this working package was to carry out an analysis of global land use. It intends to examine, in addition to the actual land use, the fields of human settlements, transport, infrastructure, population development and raw material withdrawals. The approach to this work package started with an intensive literature review and evaluation. The direct land-use changes were primarily analysed, insofar as these were quantifiable. The findings of this work package are available as a table in the Appendix.

1.2 Theoretical Bases

What follows introduces the concepts used, together with a systematic, fundamental structure for the analysis of land cover changes. This entails the classification of land covers, which provide the basis for the rest of the work. Furthermore, general and agricultural causes of land covers are presented.

1.2.1 Land cover and Land use

In order to understand land covers and their underlying causes, the concepts of land use and land cover will be clarified and dealt with separately. For the better understanding of changes in land cover and their underlying causes, the concepts of land use and land cover will be clarified and distinguished from one another.

In the sixties, Burley (1961) was in favour of making the disctinction between land cover and land use. Up until then, the term land use covered two meanings: (1) The use or the utilisation of the soil and (2) the use or the intention, or the intention to use the fruits from the soil. The latter contains, in addition the (physical) environment, where the actions are taking place, which caused confusion among scientists, because the meaning of land use had been interpreted differently according to each sector. In order to better differentiate both meanings, Burley suggested the term land cover. It includes the cover of the land surface not only by vegetation, but also by anthropogenous development. In this connection, the significance of the soil for humans is not taken into account.

Up to now, the English language expressions “land cover” and “land use” have established themselves in international environmental research. Examples of research projects include the NASA Land-Cover and Land-Use Change (LCLUC) Program, Global Land Cover Facility (GLCF), UN Land Use, Land-Use Change and Forestry (LULUCF), (USGS) Land Cover Institute (LCI) or the Land-Use/Cover Change (LUCC) research project of the International Geosphere-Biosphere Programme (IGBP) and Human Dimensions of Global Environmental Change Programme (HDP). German uses many synonyms: for land cover (*Landbedeckung*) the word *Bodenbedeckung* (canopy) is also used, the terms *Landschaft* or *Landschaftstyp* (landscape and landscape type) are used, common synonyms for *Landnutzung* (land use) are *Flächennutzung* (literally: utilisation of the surface), *Bodennutzung* (soil utilisation) or *Landschaftsnutzung* (utilisation of the landscape). The meanings of all these synonyms are partly identical. In this work, however, the terms translated from English “land cover” and “land use” will be used.

The Land-Use/Cover Change (LUCC) research project, which, with its Agenda and development planning laid down the foundation for the subsequent research projects (IAI, APN, START, NASA-LCLUC, Millennium Ecosystem Assessment) with regard land use and land cover changes, described land cover as the biophysical status of the surface of the soil and of the underlying subsoil and comprises biota, soil, topography, surface- and ground waters, as well as built-up structures (Gutman 2004; Turner 1993). Using the numerous biophysical parameters, a distinction can be made between land covers types. Similarly, different classifications can be constructed depending on scientific purpose (Turner 1993). Typical broad-interpretation classifications of land cover include for example, forests, grassland, tilled land, wetlands and non-biotic cultivation. Appropriate sub-classifications are boreal and tropical forests, savannahs and steppes, villages and cities.

Any changes in biophysical land covers, whether they are anthropogenous or not, will directly affect biodiversity, primary production, soil quality, runoff and deposition rates as well as the sources and sinks for most material and energy flows (Turner 1995). The local environment (bio- and geosphere with its greenhouse emissions and water cycle) is, therefore, immediately concerned. If similar land cover changes arise at other places, their cumulative impact can attain regional, supraregional or even global dimensions (Steffen, Tyson 2001; Sanderson 2002).

Land cover changes can be defined in two categories: conversion and modification. Conversion means the entire replacement of one cover classification by another cover classification (Turner 1993 and 1995). Deforestation and the burning of trees and other vegetation, in order to, for example, grow cereals, is a typical process of full conversion of forested areas to tilled land (Nepstad et al. 2001; Morten et al. 2006). Other land-cover conversions can be changes from forest to pasture (Fearnside et al. 1998), tilled land to dwelling settlements (Seto et al. 2011), grassland to forested area (renaturation) or dry land to tilled land (Mitchard et al. 2009).

Modifications, in contrast, refer to subtle land cover changes, which influence the characteristics (features, properties) of the land cover classification, without renewing the overall classification. Typical modification processes are the thinning out of forests by selective lumbering in the Amazonas Basin (Nepstad et al. 1999) and over-grazed grassland (Fuls 1992). At the present time, most of land-cover changes can be ascribed to human utilisation (DeFries et al. 2004; Ellis et al. 2008).

The term land use means, according to the LUCC Project, the manner in which the biophysical characteristics of the land cover are manipulated by human activity, as well as the premeditation of the manipulation. The term goes, thereby, above the purely physical form of cover of the land surface and emphasises the dimension. The typical intentions include agriculture, pasture, forestry, the extraction of soil resources and settlement and are implemented with specific means dependent on the intention. Examples include the use of fertilisers and pesticides, watering for mechanised agriculture in dry areas, the introduction of grass varieties for grazing animals or deforestation (Turner 1993 and 1995).

In the same manner as for land-cover changes, the use of land cover can alter completely (for example from forestry to agriculture) or modify by degrees (for example intensification of agriculture). Land-use changes, for example, are the shift from extensive to intensive pasture, or intensive tilling to ceasing agricultural use of the corresponding surfaces.

1.2.2 The schematic basic structure for land-cover changes

Land covers can undergo changes by natural processes (for example climatic fluctuations, such as longer drought periods) or by anthropogenous utilisation practices (for example agriculture). Since natural changes are not the object of this work, what follows will deal with the relationship between land-use and land-cover. This is necessary in order to render the origin of changes in land cover as well as the analysis of the conversion of residual areas into agricultural surfaces.

Up until now, basic theoretical structure for land-cover changes has been able to establish itself in environmental research, or Land-Change Science. One the one hand, this is rooted in the necessity to differentiate between land use and land cover, in order to explain the interactions between socio-economic and bio-physical processes (Burley 1961; Lambin, Geist 2006). Changes in land cover cannot be understood without the knowledge about the compelling land-use changes and their relationship to anthropogenous causes (Ojima et al. 1994). The theories, which should provide the basis for comprehensive, multidisciplinary and cumulative research, still remain within the main remit of (environmental) science and are a matter of controversy (van Wey et al. 2005).

Another reason can be found in the various scopes of the categories of land use and land cover, which gave rise to the corresponding concepts. From a biophysical and spatial point of view, land cover is mainly the remit of natural and earth sciences. Land use, on the other hand, is primarily positioned within the humanities, agricultural sciences, economics, politics and planning. Every science possesses various theoretical and methodological approaches. Understanding the essence of land use and land cover changes and their impact necessitates superordinate interdisciplinary theories and the concerted efforts from the natural and earth sciences as well as from the humanities (Meyer 1998; Lambin, Geist 2006).

Since no integrated theory could evolve, many empirical works, mostly case studies, have contributed to the better understanding of land use and land-cover changes by verifying various theoretical orientations under certain conditions (van Wey et al. 2005; Lambin, Geist 2006). From the empirical works, an array of flow diagrams facilitating the understanding of land-cover and land-use situations has been prepared (Green et al. 2005).

For example Figure 1 by Turner et al. (1995) illustrates land cover changes as a system that must be seen as involving the interaction of humanity and the environment or as a socio-ecological system. It demonstrates the central role of land managers and emphasises the importance of reciprocation. This basic structure is, however, less suitable for the description of land-cover changes. Nearly all arrows are double arrows, which illustrates the complexity of the relationships, but complicates empirical evaluations.

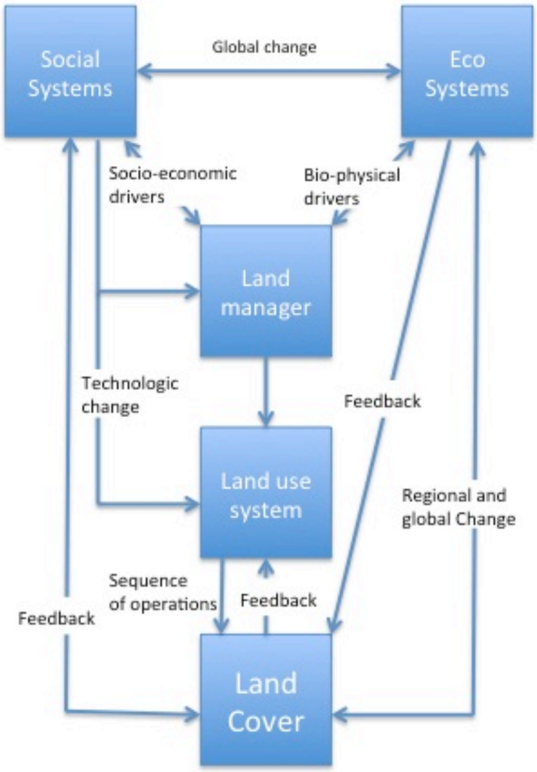

Figure 1: Flow diagram describing land use and land cover situations. Adapted from Turner et al. (1995).

The model represents the basic circumstances, processes and progression of land-cover changes and provides a breakdown of the drivers determining land cover into social, direct and biophysical sources (Figure 2). In this model, land-cover stands in a systematic relationship to land use and the causes of its utilisation. Societal driving forces determine what needs have to be satisfied the various land-uses (N1 and N2). These underlying anthropogenous causes lead, in the course of time, to soil-relevant measures requiring the manipulation of soil cover by direct treatment. The manipulation applies either to the change (modification B2 or conversion B3) or the retention of the existing land cover (B1). The ecologic consequences of the use of land covers impact the original driving forces by their effect on the environment. The changes in land cover can also reproduce themselves at other places, thereby attaining global proportions, which, in turn affects local physical systems. Independently of the impact on the environment, changes in the driving forces trigger, with the passing of time, a new type of land use, which then harbours new repercussions for land-use/land-cover systems.

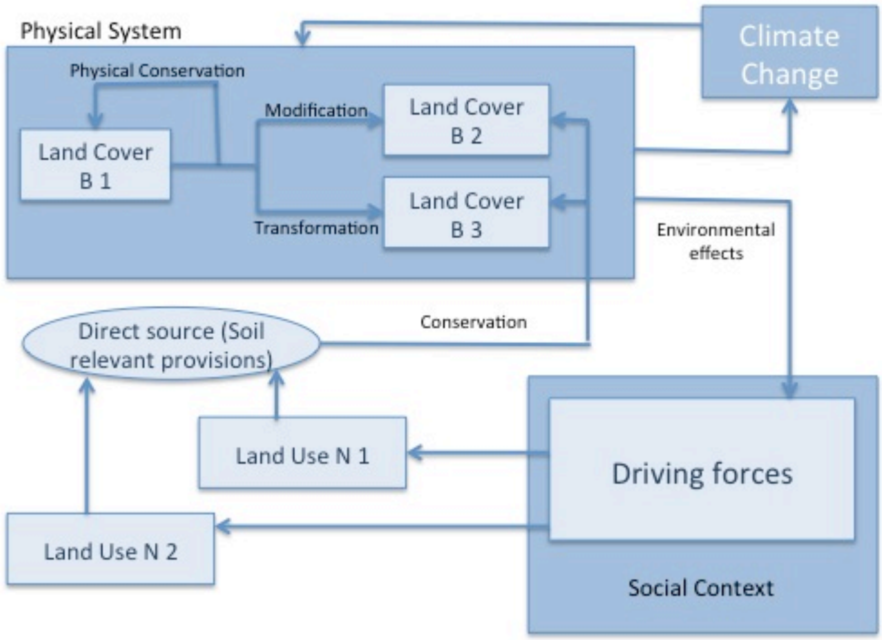

Figure 2: Schematic representation der interaction between land-use and land-cover. Adapted from Turner et al. (1993)

1.2.3 Recording land-cover changes

In terms of methodology, land covers can be directly observed from remote-sensing image data (Lo 1986) or found in secondary statistics, such as census data of the FAOSTAT. For data recording, not only the remote-sensing method, but also census surveys, the land-cover types are sub-divided into a thematic certain classification system. Classification systems are normally hierarchically structured with several levels with various degree of detail and contain criteria to distinguish land-cover classifications from one another (Anderson et al. 1976) (Fig 3).

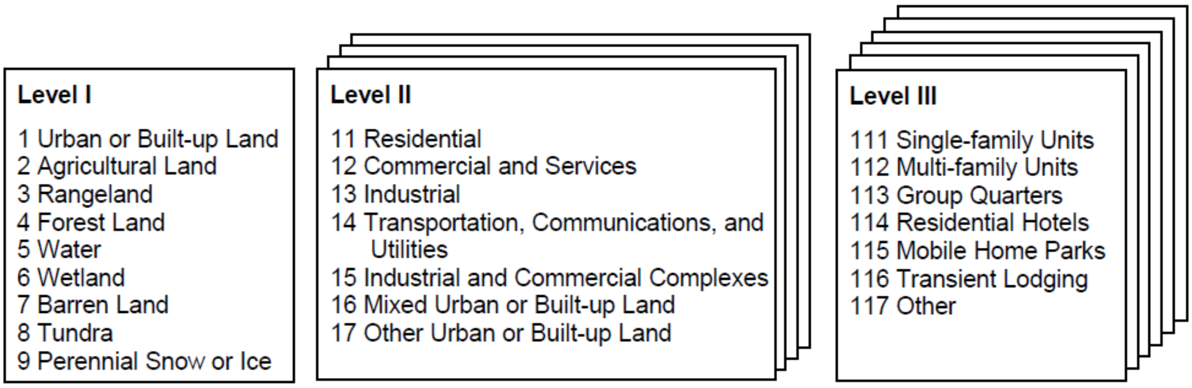

Figure 3: Classification levels des Land Use and Land Cover Classification System des US Geological Surveys (USGS). Source: Anderson et al. (1976)

In order to determine land-cover changes as precisely as possible, the factors time and space must be taken into account and a classification system established (Schneider 2003). Usually, a simple comparison of successive land-cover maps or of census data is necessary for the observation and description of land-cover conversions. In contrast, the recognition of land-cover modifications requires in part a representation of the land cover on which the surface characteristics continually change in space and time. The representation enables the locating of changes, for example in tree density, primary production or growth phase length. In secondary statistics, unlike primary statistics 3 – land-cover modifications cannot be detected.

Information concerning land-use can, on the contrary, be determined mainly by local analyses or prior knowledge (expert knowledge) (Schneider 2003). The close connexion of land-use with land-cover, however, make it necessary to link household survey, census data and market information to remote sensing and geographical information systems (Fox et al. 2004). Is a settlement area, featuring in particular buildings and streets, a land cover? If one speaks of industrial zones or residential areas, with for example administrative building, then one means the land use with the functional dimension mentioned. This renders obvious the fact that, in contrast to land-cover, the change in land-use cannot be exclusively detected by satellite images. Then, supplementary descriptive data concerning land-use is always necessary (Feranec et al. 2007) (Fig 3).

The great efforts of environmental sciences made to document changes in land-cover and land-use in order to draw future scenarios and models for sustainable land uses, however, have led to further challenges: in spite of the continuous improvement in satellite technologies for remote sensing, great data gaps concerning various land-cover classifications, thereby creating knowledge gaps on the causes and dynamics of these land-cover changes. Most of the studies focused on the deforestation process in humid tropical regions, which can be observed by simple means (Heilig 1995; Lambin, Geist 2006). Uncertainty persists on the description of the extent and the changing pattern of dry tropical forests, changes in wetlands, soil erosion, dry land degradation, expansion of built-up areas, as well as lifestyle-driven changes (Lambin, Geist 2006).

Furthermore, the number of data records for land covers from local up to global level is diminishing significantly (Lambin, Geist 2006). The difficulty lies with the fact that documenting global land cover is limited by poor resolution of remote sensing images. In order to draw precise conclusions about land-cover changes, the remote sensing satellite images possessing high resolution, must be generated; also this must be made over many decades. (Lambin, Geist 2006). This effort is, however, a question of costs (Peterson et al. 2004). This is the reason why mostly annual snapshots are used to monitor worldwide land cover changes, whereas, for the analysis of local land cover changes, high-resolution and continuous images are generated.

The use of various remote-sensing methods makes it difficult to compare land-cover changes with one-another at the same level, as well as other transposing them to other levels. It is not surprising, therefore, that up until now, no internationally accepted classification system for land-cover exists (Di Gregorio, Jansen 2000).

A further problem resides in the fact that a certain type of use, such as extensive grazing, can be fully assigned to a certain land cover, such as a non-cultivated grass surface. Conversely, a certain land-cover can stand for many types of use (forest area can be used for species protection and leisure). Furthermore, a certain utilisation system can comprise the upkeep of various land covers, for example: if a particular agricultural system combines certain cultivated areas, wooded areas, improved grassland and settlements (Meyer 1998), this can result in classification problems.

1.2.4 Land-cover classification

In essence, classification means abstraction. It is the theoretical representation of a real-life situation, using easily delineated and well-defined criteria (Di Gregorio, Jansen 2000). That is to say that before classifying land-cover types, exact specifications must be made. In principle, it can be noted that classification systems exist in mainly hierarchic form. In doing so, classification criteria are selected, which only apply within one class and are grounded on a more general criterion from the outset. This creates many levels, which develop into a classification tree starting with very general classes and branching out into detailed sub-classes (Anderson 1976; Di Gregorio, Jansen 2000).

As of today, there is no internationally recognized classification system. This is owing to the fact that every person dealing with these matters has a different concept of land cover classification or fundamental understanding depending on their research focus. Since this work specialises on the conversion of residual areas resulting from the creation of agricultural surfaces and the concept of residual area does not possess any own classification, the classification of residual area must be redefined.

In order to analyse the conversion process resulting from the creation of agricultural surfaces, one must establish exactly which land covers count as agricultural and which land covers are defined as forests. At the highest level, the whole classification refers to three FAO classes: agricultural area, Forested Area and other land. Together, these three classes form the landmass of a state, without the bodies of water found within that state.

1.2.5 Definition of agricultural surfaces

According to FAOSTAT, the classification of agricultural surface comprises all surfaces defined as arable land permanent crops, permanent meadows and pastures (FAOSTAT 2012):

- Arable land means the surfaces, which are temporarily developed for agricultural crops, for pastures, for mowing, for meadows or for vegetable garden or which have been lying fallow for fewer than 5 years. Abandoned land, which stems from shifting cultivation, is not included and is not considered agricultural surface according to the classification criteria of the FAOSTAT.

SEEC nomenclature classifies agricultural land covers in a more detailed manner. For the further subdivision of arable land, the classifications including rain-fed annual crops and irrigated agriculture can be drawn into consideration.

Rain-fed annual crops include all crop rotation types and fallow land, which does not have to be continuously watered. Typical rain-independent crops are cereals, vegetables, fodder and root crops. Irrigated arable land, on the other hand is continuously or periodically sprinkled with water, that is to say, they are independent of rain and characterised by a permanent irrigation scheme (irrigation canals, waste-water system). The best-known crop, which is permanently submerged, is rice (SEEA 2010).

- Surfaces with permanent agricultural crops are included in the sub-classification of permanent crop. Permanent cultures are sown or planted once and cover the surface for some years, without being replanted after each yearly harvest. Examples of permanent crops are cocoa, coffee and rubber. This classification includes, likewise, flowering shrubs, fruit trees, nut trees and vines. Excluded in the classification are trees, planted primarily for logging (FAOSTAT 2012).

The SEEC classification system defines permanent cultures in the same way and makes plain that permanent crops do not have rotation and include agriculturally used plantations (SEEC 2010).

- Permanent and non-permanent pastures comprise the surfaces, which have been coved for longer than five years with herbaceous crops for fodder. This includes surfaces with cultivated (for example pastures) as well as wild-growing plants (for example prairie) (FAOSTAT 2012).

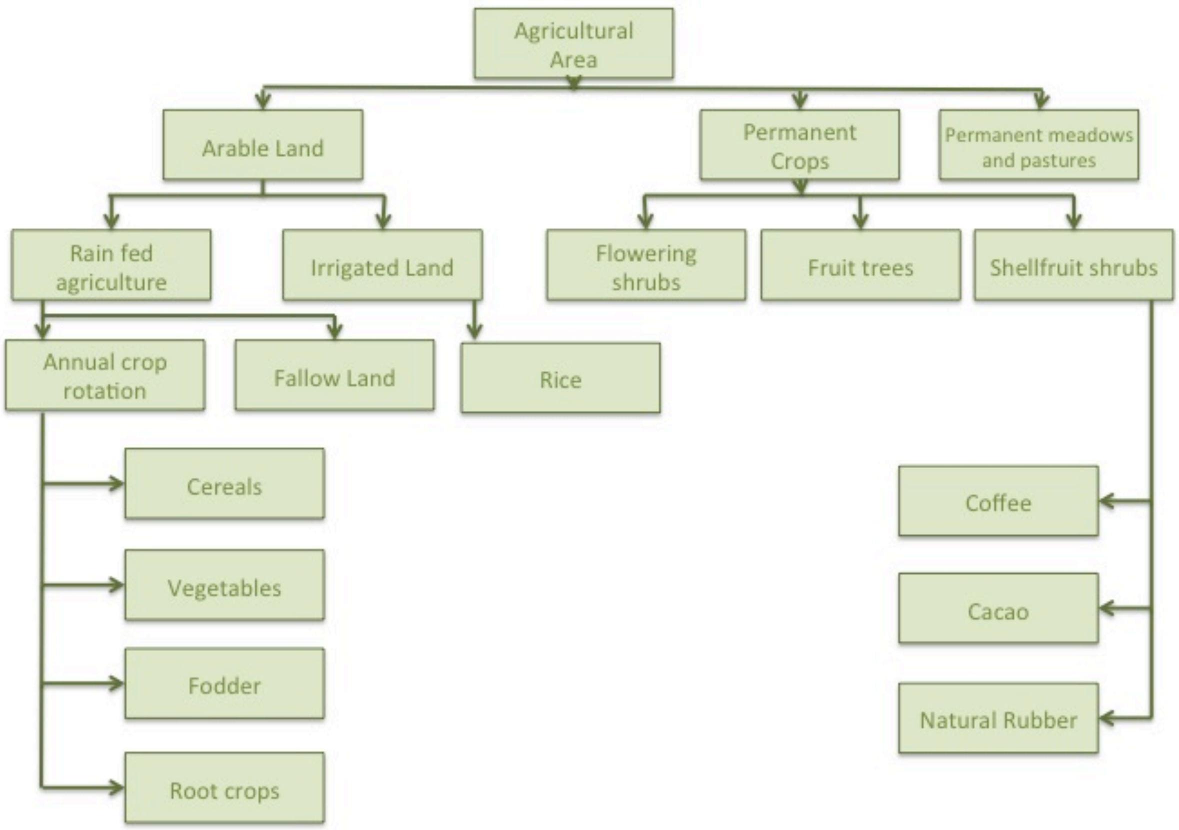

Figure 4: Classification of the agricultural surfaces. (Brillinger 2012)

For the land-cover matrix, this classification, however, also includes woodland, because it can be assumed that the prevailing land use in this classification will cover various forms of meadows (GEO-4 2006). In fact, the demarcation between woodland, pastures and green land can be very difficult, because they all have similar vegetation covers and are generally not intensively used for animal husbandry.

It is furthermore not clear, to which class the “woodlands” belong. Should the distinction be made between forested area or, as with the FRA-class “other wooded land”. Especially the latter class is not considered as belonging to FAOSTAT and, in FRA, it is not considered to be agriculturally used land. For this reason, wooded areas are not included in the original FAOSTAT’s sub-class of permanent pasture and pastures.

SEEA’s definition delineation is more useful. It distinguished between meadows, natural and near-natural grassland. Meadows are cultivated areas, natural and near-natural grass areas, conversely, are non-managed areas, which are often found in places with uneven or rough surfaces and which are characterised by the maintaining of the botanic diversity. Additionally, surfaces with thin vegetation cover can be classified as permanent pasture and pasture area if they are used agriculturally. These areas are open areas with little vegetation, that is to say, soil vegetation dominates, and single trees or shrubs can inhabit them. Examples of such poorly vegetated open surfaces are all forms of semi-desert steppes, such as the ecologic zone of the Sahel and the extensive transition to desert (GEO-4 2006).

1.2.6 Definition of Forested Area

In order to draw up the definition of the classification of “residual area” in the next paragraph, the first step is the distinguishing delineation to the classification of forested area, because the deforestation process should not be given priority in the analysis. Like the agricultural surface, the forested area represents a main classification point of the FAOSTAT. For a surface to be described as forest, various criteria must be fulfilled, which, however, are only of moderate relevance, because in the studies observed, they could only be partly verified. Nevertheless, they will be briefly presented here for better understanding.

A surface is classified as forest when it is larger than 0.5 ha, has trees with a height of at least 5 m and a canopy covering more than 10%. As a whole, the presence of the trees dominates and agricultural and urban land-use forms are missing. The areas that have not yet reached a 10% canopy cover, or a height of 5 m and typically belong to forested areas but are felled, will in all likelihood return to the state of forest (FAOSTAT 2012).

According to these criteria, this classification comprises forests in national parks, nature reserves and other protected areas, trees as windbreaks, firebreaks, tree corridors and plantations (such as rubber, cork and oaks), whose primary use is for forestry or protective aims, mangrove forests in intertidal zones, as well as land left fallow with regenerating tree stocks from shifting cultivation. Forestry and protection measures belong, accordingly, to one of the classification criteria for forested areas and facilitate the later analysis of case studies on conversion processes. Conversely, tree stocks in agricultural production systems, such as orchards and agroforestry systems, such as urban parks and gardens (FAOSTAT 2012).

The classification system of the SEEA has established criteria comparable to those of FAOSTAT for the definition of forests, but divides the main classification into forest land and transitional woodlands. What is referred to as transitional woodlands comprises grasslands with poor tree cover, real clearings and new plantations, regeneration surfaces in transitional regrowth, as well as early phases of revegetation by forests on abandoned land (SEEA 2010). The differentiation between mature and transitional forest has been taken over in order for clarity’s sake.

1.2.7 Definition of residual areas

When a land cover is not classified as agricultural land or forest area it falls under the main FAOSTAT classification of “other land”. The difference to other main classifications resides in the fact that no further criteria to determine other land surfaces exist. Rather, it represents a remainder class or miscellaneous collection of not-further-defined areas or surfaces, bearing no primary relevance to the work focus or to the inquiry. In the further course of this work, the concept of “residual areas” will be used, even though this classification stands for various types of land covers.

In the FAOSTAT, the classification of “residual areas” is only assigned broad-category land cover sub-classifications. It includes built-up areas, barren land and other wooded land. The worldwide trend shows that built-up and infrastructure areas are increasing (Seto, Shepherd 2009; Seto et al. 2011). Furthermore, the surfaces that are classed as residual areas, agricultural surfaces and forest areas must be excluded. These are abandoned soils from shifting cultivation, land that has been lying fallow for longer than 5 years and agroforestry surfaces.

The Global Forest Resource Assessment 2010 includes the sub-classification of tree-covered residual areas to the classification of residual area. By doing so, it also adds tree stocks in agricultural production systems, such as agroforestry systems and tree plantations, whose creation was mainly aimed at logging, to the residual areas. In addition, the FRA defines other woodland (FRA 2010).

A total of five classifications can be observed from SEEA nomenclature, which can be considered as belonging to residual areas: agriculture forming a mosaic-type landscape, shrubbery, bushes and moorland, barren land, continuously snow-covered glaciers and ice fields, as well as open wetlands. Snow-covered surfaces need not be taken into account for the following investigation of conversion processes.

FAOSTAT, FRA and SEEA feature the following classifications of residual areas (Fig 5):

- Areas with less tree-cover and lower tree height or surfaces with smaller tree cover, but with bushes, shrubs and / or herbaceous plants are included in “other wooded lands”. This includes herbaceous or bushy savannahs, as well as undergrowth in semi-desert areas. The classification comprises, therefore, shrubberies, bush-and moorland with or without tree stocks, mangroves in dry areas and alpine tree vegetation.
- Other “agricultural and wooded land” includes all the surfaces, which are not classified as agricultural and forested areas. These comprise abandoned areas from shifting cultivation, fallow land older than 5 years and agro-forestry land. Agro-forestry lands, however, are assigned to the mosaic-type agricultural surfaces.

  Mosaic-type agricultural surfaces describe surfaces with several forms of use. Crops can be cultivated together with permanent crops on one same piece of land and / or under the forest trees. Crops, meadows and / or permanent crops are cultivated next to one-another and there are land covers in which agricultural crops and pastures with natural vegetation or with natural surfaces are closely linked. The most common forms of mosaic agriculture are agro-forestry systems. In agro-forestry sees the integration on one and the same surface of not only perennial trees (for example fruit trees, palm trees, timber) but also annual agricultural crops (SEEA 2010).
- The definition of the classification of “barren land” harbours a difficulty. The English expression “bare land” or even the concept of barren land has different translations into

German. On the one hand, it describes the expression “waste land”, on the other it can simply be translated as unused area. The translations can, however, be interpreted differently. The concept of “barren land” generally defines a land cover characterised by the sterility of the soil owing to climatic, orographic, physic-chemical or anthropogenous conditions. Barren land resulting from anthropogenous action is often attributed to excessive agricultural exploitation (Geist and Lambin 2001; Qi and Lou 2006). In particular in arid and semi-arid climatic zones, barren lands are constituted by exhaustion, leaching and erosion of the fertile soil layers (Dregne 2002). Conversely, an unused surface must not necessarily be desertic or eroded. Rather, the expression refers to natural land covers, which haven’t yet been assigned a human use, but possess economic potential.

In the classification system of SEEA, the classification description of “bare land” covers both meanings. The classification comprises natural, undeveloped, sparsely vegetated to bare land surfaces. As a result, sparsely vegetated surfaces, bare soils, burned areas, abandoned open-air mines, cliffs and sandy soil coverings, such as dunes and beaches can all be included under this concept (SEEA 2010).

- The last classification of interest is that of the “open wetlands”. Unlike the wetlands covered by trees or forest, which are classified as forested area, open wetlands are characterised by the fact that these areas feature neither tree cover, nor forest, and that the surfaces are submerged under brine or acidic water. For example barren bogs, such as peat bogs or peat meadows, salt marches, wet tundra or mud flats (SEEA 2010).

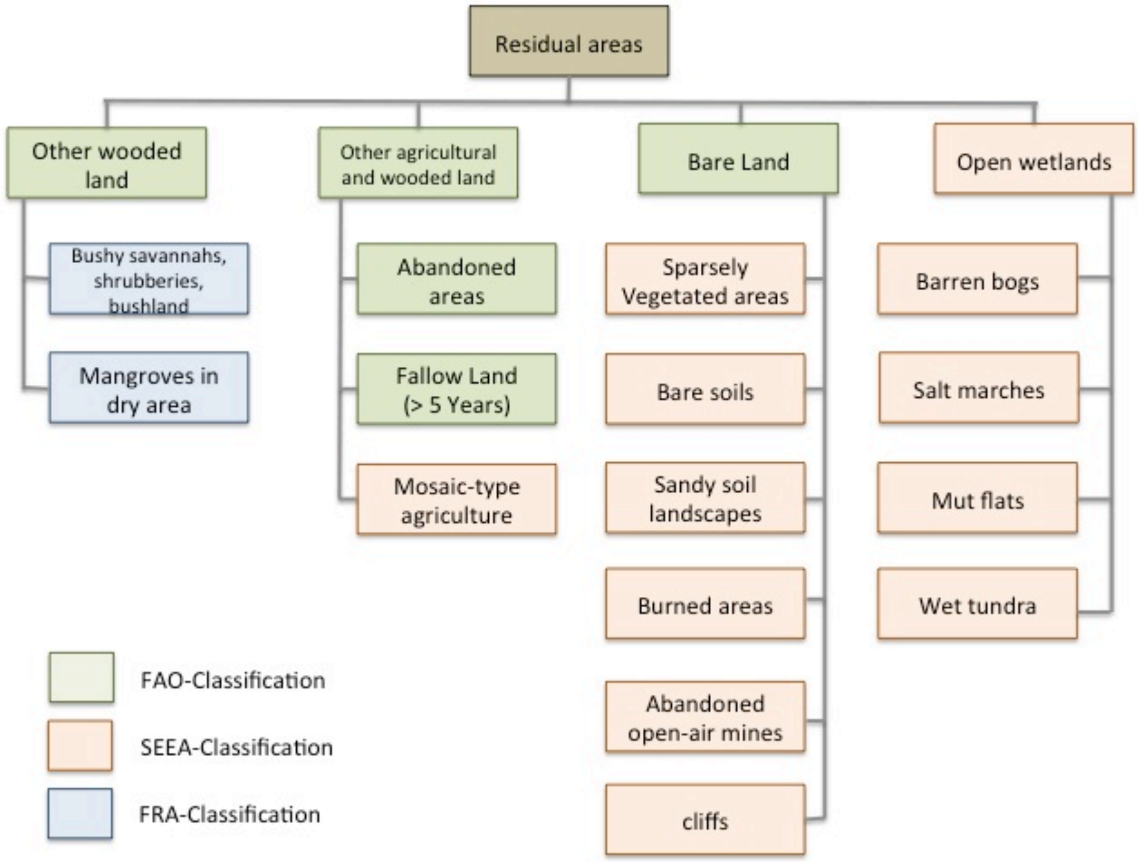

Figure 5:Classification of residual areas. (Brillinger 2012)

1.2.8 General and Agricultural Reasons for Land-Cover Changes

Human-induced land-cover changes stand, according to Turner et al. (1993), in direct connection with human land utilisation (Fig 2). Human land uses exert a direct influence on the environment, thereby generating changes in land cover – in this case, the change from residual areas to agricultural surfaces. Therefore, the difference between direct and indirect effects is made.

This work concentrates on the direct driving forces of the changes from residual areas – agriculture. Indirect causes, which are responsible for the changes in utilisation of agriculture, should not be disregarded. Up until now, research concerning land use and land-cover changes has concerned itself mostly with deforestation. Even without observing the deforestation process, relevant literature provides an array of identifiable cause, which can be a helpful orientation for the conversion process of residual areas.

Proximate Causes

Proximate causes comprise the physical activity upon a land cover and can usually be attributed to a series of repeated activities, such as agriculture, forestry and infrastructural measures (Lambin, Geist 2006). In the literature concerned with deforestation, proximate causes are classified in three broad groups (Mainardi 1998; Kaimowitz, Angelsen 1998; Contreras-Hermosilla 2000): agricultural spread, logging and infrastructural expansion. Geist and Lambin (2001) completed this grouping with specific variables, by checking 152 case studies on deforestation and analysing them from the point of view of causality. Fig 6 shows the list of variables, which are relevant for the work package for agricultural expansion

Agricultural Spread	Shifting agriculture	Traditional shifting agriculture Colonial shifting agriculture
	Permanent cultivation	Small scale subsistence farming Commercial agriculture Agricultural development projects
	Stock farming	Small scale (family) stock farming Large scale stock farming Unspecified
	Colonization Transmigration Population transfers	Spontaneous transmigration Local transmigration Military transmigration Agricultural settlement Industrial forest-plantation settlement unspecified

Figure 6: List of variables for the spread of agriculture identified as a direct cause of deforestation. Extract from Geist and Lambin (2001).

Agriculture is made responsible for an array of changes in eco-systems (Tilman et al. 2001; Green et al. 2005). Driving forces, such as population and economic growth can lead to an increased need in foodstuffs, resulting in agricultural expansion. This relationship need not be deterministic. An alternative consequence on the evolution of the population and economy, can also be the intensification of existing agricultural surfaces and specialisation of agricultural production on the one hand, but also lead to marginalisation and abandonment of land on the other (Boserup 1965).

The intensification of agriculture aims at increasing crop yield on a given area within a given time unit. In order to reach that goal, the amount of applied work force and capital is increased. Typical intensification methods are breeding, watering, organic and inorganic artificial fertiliser, green manuring, pest and weed management, crop rotation and reduced of fallow land duration. In analysing the conversion of residual areas, the intensification can be a cause insofar as fewer, intensively used, disused or abandoned agricultural surfaces, which are apparently classified as residual areas, are returned to the agricultural surfaces thanks to an intensification process.

Land abandonment describes the withdrawing from agricultural production, which often follows marginalisation processes in agricultural and rural regions. Agricultural marginalisation is a process driven by a combination of social, economic, political and ecological factors, where agriculture is adapted to a specific area. The access to the market, the availability of competent authorities, qualified labour, as well as the availability of credits for farmers, infrastructures and cultural factors can be the driving force for marginalisation. Marginalisation and abandonment of agricultural surfaces often take place in remote areas with disadvantageous economic and social conditions or applies to less fertile soil (Geist 2006).

The expansion of cultivated areas and pastures is by far the most common prevalent reason for deforestation (Geist, Lambin 2001). It comprises land-cover conversions by permanent crops, pasture formation for livestock, shifting cultivation and agricultural colonisation. Permanent crops and shifting cultivation, in particular, belong to the robust direct causes, which vary only insignificantly (Geist, Lambin 2001).

“Shifting cultivation” can be described as temporary agricultural form, which is often the cause of deforestation. This concept can, however, be defined and interpreted in various ways. In particular, the definitions of “traditional” shifting cultivation, which is usually practiced by indigenous peoples, and the “colonised” shifting cultivation or slash-and-burn agriculture are still being debated. Traditional shifting cultivation must not necessarily lead to deforestation if the cycle is long enough. In some regions of the Earth, humans and forests have co-existed thanks to that type of use for centuries. Fields in forest clearings are cultivated and harvested for one or more years and left fallow for some time, so that secondary vegetation can regrow. When the cycle length has to be reduces, for example by population growth or lack of availability of agricultural surfaces, then the full restoration to mature forest cannot take place (Fox 2000).

Even in the case of “long-term cultivation”, the various types must be examined, because every form impacts differently on land cover. Differences can be made between small and extensive cultivation and commercial and subsistence agriculture. Geist and Lambin’s case study on deforestation showed that the spread of cultivated crops for private use was cited three times as often as direct cause as the spread of commercial cultivation. Even when commercial agriculture was indicated as a cause, the fault was more often attributed to small farmers, such as plantation cultures (Geist, Lambin 2001). With globalisation and increasing urbanisation, however, capitalised agricultural systems, which produce for consumers in distant markets, gain in importance (Rudel et al. 2009).

Animal husbandry is closely related with deforestation, especially in humid tropical lowlands, such as Brazil (Walker et al. 2000). Geist and Lambin report that, in only 6 % in Asia, 16 % in Africa and 82 % of all studies examined show that animal husbandry is responsible (Geist, Lambin 2001, 26). Even though animal husbandry is mainly practiced in large farm holdings, it is not unusual that small holders increase their livestock. Factors, such as low work and supervision, transportability, low material usage, biological and economic flexibility, low production costs and reliable cash-flow sources favour the introduction of animal husbandry (Evans et al. 2001).

Furthermore, agriculture can spread out in certain parts of the forests as a result of spontaneous or planned rural settlements. Known examples for this are found in Brazil and Indonesia. There, state-sponsored “transmigration” projects for the resettlement of smallholdings in hitherto uninhabited regions are in place (Fearnside 1997; Peres, Schneider 2012). According to the analysis by Geist and Lambin, this form of colonisation happened in around 40 of cases, but it is less widespread in African than in Asia and Latin America (Geist, Lambin 2001).

Underlying causes

By “underlying causes” are meant fundamental social driving forces, which underlie more obvious, proximate causes. They consist in a complex of social, political, economic, technological and cultural variables and act, unlike proximate causes, not only at local, but also at national level. Within global environmental research, a series of fundamental driving forces behind land-use changes are under investigation, and five factors always crop up again as underlying cause: population, economic development, institutions, technology and culture (Mather 2006). In what follows, only population growth, economic development and institutional causes are expanded upon. Since world population growth has doubled in the past 40 years, demographic factors, especially population growth, is expected to play a major role in land-cover changes (Hassan et al. 2005). First of all, the relationship between population growth and the increasing need for resources can result in an intensifying of cultivated or newly tapped areas. Case studies show, however, that population grown alone is not the driving force behind land-cover changes (Lambin et al. 2001).

Population grown is affected by various population dynamics, such as urbanisation, immigration and emigration, as well as changes in population density, all of which, in turn, interact with other factors, such as social organisations (for example network-building), technologies (for example the extent of agricultural yields), lifestyle (for example income, dietary patterns) and consumer behaviour (for example food supply versus cash crops) (Heilig 1995).

Next to population growth, economic development also plays an important role. It comes as to no surprise, then, because population growth and the demand for eco-system goods and services have increased as a result of globalisation. The great differences between per capita consumption in highly developed as opposed to least developed countries are named as underlying cause, whereby not only poverty, but also welfare is used to explain land-cover changes (Mather 2006, 181). A closer look reveals that economic factors comprise a number of distinct processes. They define a large quantity of variables, directly impacting the decision-making concerning land use, for example, sale price, taxes, subventions, production and transport cots, capital flows and investments, access to credits, commerce and technology (Barbier 1997). In particular, taxes and subventions are important drivers for land-use dynamics and the land-cover changes it entails (Hassan et al. 2005).

Another factor, which connects demography and economy on the one hand, and, on the other, changes land-use decisions, is institutions (political, legal, economic and traditional). Institutions regulate, amongst others, the property rights to the soil and play an omnipresent role in land-cover changes. The access to land, work, capital, technology and information is structured by local and national guidelines and institutions (Batterbury, Bebbington 1999). Thus, for instance, governments encouraging a reduction in birth rates and transmigration, and at the same time, in the economic sector, control prices, subventions, access to credit, infrastructure maintenance and exports. It is said, especially concerning economic guidelines, that they are closely interrelated to the dynamics driving land dynamics. Factors, such as market liberalisation, privatisation or fall in currency are often cited in connection with land-use changes (Kaimowitz et al. 1999; Mertens et al. 2000; Sunderlin et al. 2001).

2 Analysis and Scenarios on Global Land Use, WP 1.1

For the Analyse of global land use, as described in work package 1.1, a total of 33 international studies as well as data collections were selected. These data collections were subsequently verified in the light of three selection criteria:

1 Plausibility of the classification and categorisation

2 Comparability at horizontal level with other sets of data

3 Quality with regard vertical comparability over time periods to be defined

Concerning 1): A clear definition, which enables unambiguous, non-contradictory, and unequivocal attributability to individual categories, is essential for further work packages. Furthermore, this point also includes the system boundaries of the individual studies and sets of data. Though there various GIS sets of data exist, they often expand across state boundaries, and are, therefore not exploitable for this project.

Concerning 2): In selecting sets of data, these were, as far as possible, compared within the categorisations, in order to detect discrepancies. Sets of data from studies that showed great deviations were discarded.

Concerning 3): In order to identify land-use changes, vertical comparisons over certain periods of time are a prerequisite. Even if in the past years, thanks to improved methodology in collecting data and information, many new studies and data collections have been published, only a few fulfill the desired comparability over long period of times, so that, at this point also, many sets of data did not fulfil the requirements.

After verification, three data collections were selected for further processing and analysis.

These sets of data were fed into a matrix and evaluated. Global land use for all states is displayed in the matrix. The change in land use is made visible, even not only procentually, but also in absolute for all categories on the one hand, on the other for all states of the world. In this way, the “directions” of land-use change are clearly displayed.

In order to render certain the influences of other drivers visible, the matrix was enhanced by the selection of other records. There, again around 20 studies and data sets concerning the criteria described above were verified and selected. These sets of data contain further statistical information, amongst others concerning Population development, urbanisation, urban growth, infrastructural measures, economic development and the extraction of raw materials. By merging the data in the final matrix, these can now both countries, regions and continents, as well as provide a global overview on land use, land-use changes and changes in a certain number of already identified driving forces.

2.1 Analysis of global land use in their various Charaterisations

2.1.1 Forested Area

Definition:

„Forested Area is the land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly unof agricultural or urban land use. Forest is determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 metres (m) in situ. Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 10 percent and a tree height of 5 m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate. Includes: areas with bamboo and palms provided that height and canopy cover criteria are met; forest roads, firebreaks and other small open areas; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest; windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20 m; plantations primarily used for forestry or protective purposes, such as: rubber-wood plantations and cork, oak stands. This excludes tree stands in agricultural production systems, for example in fruit plantations and agroforestry systems. The term also excludes trees in urban parks and gardens. (Source: http://faostat.fao.org/)

Underlying data bases

Forest Resource Assessment (FRA) URL: http://www.fao.org/forestry/fra/en/

Data quality / Type of data recording

Data from 2000 mainly: Official data reported on FAO Questionnaires from countries

Data from 2009 manual estimation

Deviation / Gaps in Data bases

For 4 states in the Austro-Asiatic space, no data are available.

For 20 European countries, no data are available.

Trends

Table 1: Land use changes Forested Area

Forested Area	Changes in km ^{2}	Changes in %
China	298.610	16,87
USA	38.270	1,27
India	30.440	4,66
Ruanda	910	26,45
Uruguay	3.320	23.51
Tunisia	1.690	20,19
Brazil	-264.210	-4,84
Australia	-56.200	-3,63
Indonesia	-49.770	-5,01
Nigeria	-40.960	-31.18
Uganda	-8.810	-22,77
Pakistan	-4.290	-20,27

Asia/Australia:

Total forested area in Asia and Australia covers around 20 % (7,838,960 km^2, 2010) of the total land surface. From 2000 to 2010 the forested area increased by around 0.02 % (153,510 km^2). In 22 states forested areas are decreasing. In 17 states forested areas are increasing. In 30 states forested areas remained unchanged or could not be quantified in more detail due to lacking data.

America:

The forest covers around 40.35 % (15,697,440 km², 2010) of the whole continent. From 2000 to 2010 the forest area decreased by around 2.49 % (400,750 km²). In 26 states, forested areas are decreasing. In 10 states forested areas are increasing. In 15 states, forested areas remained unchanged.

Africa:

The total forest area of Africa covered 2010 around 22.75 % (6,744,190 km²) of the whole continent. From 2000 to 2010, the forest area decreased by around 4.82 % (341,450 km²). In 39 states, forested areas are decreasing. In 10 states forested areas are increasing. In 8 states forested areas remained unchanged.

Europe:

The total forest area of Europe covers around 46 % (10,016,370 km², 2010) of the whole continent. From 2000 to 2010 forested areas decreased by around 1 % (122,874 km²). In 11 states, forested areas are decreasing. In 24 states, forested areas are increasing. In one state, the forest area remained unchanged.

2.1.2 Other wooded land

Definition:

"Land not classified as Forest, spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly unof agricultural or urban land use. "

(Source: Global Forest Resource Assessment 2010 – Terms and Definition)

Underlying data bases:

FAO. 2010. Global forest resources assessment, 2010-Main report. FAO Forestry Paper 163. Rome, Italy. http://countrystat.org/for/en

Data quality / Type of data recording

Officially nominated country correspondents in collaboration with FAO staffs have compiled the country reports. Prior to finalization, these reports were subject to validation by forestry authorities in the respective countries. The report contains data sources, original data and documentation of adjustments made to meet the definitions and classifications used in the global forest resources assessment.

Source: http://countrystat.org/for/cont/pages/page/metadata/en

Deviation / Gaps in Data Bases

Lots of discrepancies exist between Global Forest Resource Assessment 2000 (FAO) and the FAO Forestry Department 2010. For some states there were no data at all, for some (USA, Suriname, Brazil, Barbados, Cayman Islands, Martinique and Montserrat) there was only one set of data for 2010, therefore, the increase and decrease of 100%, which was not taken into account.

Europe: For 26 states no data are available.

Trends

Asia/Australia:

Other forested areas cover 9.64 % (3,800,830 km^2, 2010) of Asia and Australia. From 2000 to 2010 the other forested areas decreased by 39.59 % (-2.490.660 km^2). In 8 states, the other forested areas are decreasing. In 13 states, the other forested areas are increasing.

America:

Areas forested differently cover around 8% (3,143,460 km^2, 2010) of America. From 2000 to 2010 these decreased by around 25.75 % (1,090,230km^2). In 17 states, the other forested areas are increasing. In 10 states, areas forested differently are diminishing. In 24 states, these areas remained unchanged.

Africa:

Other forested areas cover 2010 around 11.83% (3,507,830 km^2) of Africa. From 2000 to 2010, the other forested areas decreased by around 25.55% (1,204,060 km^2). In 24 states, the other forested areas are decreasing. In 6 states, the other forested areas are increasing. In 15 states, the other forested areas remained unchanged.

Europe:

Other forested areas cover around 4.7 % (993,000 km^2, 2010) of Europe. From 2000 to 2010, the other forested areas decreased by around 1 % (11,190 km^2) ab. In 12 states, the other forested areas decreased. In 13 states, the other forested areas are increasing. In 5 states the other forested areas remained unchanged.

2.1.3 Primary forest

Definition:

„Naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. Some key characteristics of primary forests are:

- they show natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure and natural regeneration processes;
- the area is large enough to maintain its natural characteristics;
- there has been no known significant human intervention or the last significant human intervention was long enough ago to have allowed the natural species composition and processes to have become reestablished.“

Source: Global Forest Resource Assessment 2010 – Terms and Definition

Underlying data bases:

AO. 2010. Global forest resources assessment, 2010-Main report. FAO Forestry Paper 163. Rome, Italy. http://countrystat.org/for/en

Data quality / Type of data recording

„The country reports have been compiled by officially nominated country correspondents in collaboration with FAO staff. Prior to finalization, these reports were subject to validation by forestry authorities in the respective countries. The report contains data sources, original data and documentation of adjustments made to meet the definitions and classifications used in the global forest resources assessment. “

Source: http://countrystat.org/for/cont/pages/page/metadata/en

Deviation / Gaps in Data bases

Asia/Australia:

Data is available for only around half of the states. Extraordinary increases in Australia and New Zealand whereby the land dies not greatly change. The trend is, therefore, provisional without taking both these countries into account.

Some data gaps, mainly in the Caribbean, because the climate there does not permit primary forest. Furthermore, there is, for some countries (Honduras, Jamaica) only figures for 2010, therefore the increase of 100%. For Africa, data for Nigeria is obviously missing, as there are no figures available for 2010. Europe: 34 Missing sets of data.

Trends

Asia/Australia:

Old-growth forests cover around 4 % (1,505,170km^2, 2010) of the surface of Asia (without Australia and New Zealand). In total, the stocks of old-growth forests decreased from 2000 to 2010 by around 5 % (68,770 km^2). In 13 states, old-growth forests are diminishing. In 5 states, the surface of old-growth forests has increased.

America:

Existing forests cover around 60 % (9,058,000 km^2, 2010) of America. From 2000 to 2010, old-growth forests decreased by around 6.8% (618.490 km^2). In 13 states, old-growth forests are diminishing. In 7 states, the area that they cover is increasing. In 31 states, old-growth forests remained unchanged.

Africa:

Old-growth forests cover 2010 around 2 % (479,466 km^2) of Africa. In 2010, old-growth forests represented 7.11% of the proportion of the total forest area of Africa. From 2000 to 2010, old-growth forests decreased by around 10.65% (57,154 km^2) ab. In 11 states, old-growth forests are decreasing. In 13 states, old-growth forests remained unchanged.

Europe:

Old-growth forests cover around 13 % (2,618,870 km^2, 2010) of Europe. From 2000 to 2010 old-growth forests decreased by around 1 % (28,790 km^2). In 8 states, old-growth forests increased. In 8 states, an increase has been detected. In 8 states, the surface covered by old-growth forests remained unchanged.

2.1.4 Other naturally regenerated forest

Definition:

“Naturally regenerated forest where there are clearly visible indications of human activities.

1. Includes selectively logged-over areas, areas regenerating following agricultural land use, areas recovering from human- induced fires, etc.

2. Includes forests where it is not possible to distinguish whether planted or naturally regenerated. 3. Includes forests with a mix of naturally regenerated trees and planted/seeded trees, and where the naturally regenerated trees are expected to constitute more than 50 percent of the growing stock at stand maturity.“

Source: Global Forest Resource Assessment 2010 – Terms and Definition

Underlying data bases:

FAO. 2010. Global forest resources assessment, 2010-Main report. FAO Forestry Paper 163. Rome, Italy. http://countrystat.org/for/en

Data quality / Type of data recording

"The country reports have been compiled by officially nominated country correspondents in collaboration with FAO staff. Prior to finalization, these reports were subject to validation by forestry authorities in the respective countries. The report contains data sources, original data and documentation of adjustments made to meet the definitions and classifications used in the global forest resources assessment."

Source: http://countrystat.org/for/cont/pages/page/metadata/en

Deviation / Gaps in Data bases

Asia/Australia:

For 19 states no data are available.

America:

For 13 states no data are available. For some countries (Honduras, Nicaragua) only a few values were available, therefore the increase of 100%, which was not taken into account.

Africa:

Partly slight deviations: for example Gambia, Lesotho, in 6 states no data are available.

Europe:

Data gaps in 19 States

Trends

Asia/Australia:

Other, naturally regenerated forest areas cover around 93% (5,504,930 km^2, 2010) of the forest area of Asia and Australia. From 2000 to 2010, the proportion of the other naturally regenerated forest areas increased by around 21 % (1,439,730 km^2) within the forested surfaces. In 19 states the forest of the category are on the decrease. In 11 states, the naturally regenerated forest areas have increased. In the remaining states the surface remained unchanged or it is not possible to make a precise statement on its exact status.

America:

Other, naturally regenerated forest areas cover around 1.5% (565,134 km^2, 2010) of America. From 2000 to 2010, these forest areas decreased by around 2.1% (12,019 km^2) ab. In 11 states these types of forests increased. In 6 states, the other naturally regenerated forest areas have increased. In 20 states, old-growth forests remained unchanged.

Africa:

Other, naturally regenerated forest areas cover 2010 around 15% (4,371,533 km^2) of Africa. As of proportion of the total forest area of Africa in 2010, there was around 64.82% other, naturally regenerated forests. From 2000 to 2010 the other, naturally regenerated forest areas decreased by around 5.52% (255,646 km^2). In 60 states, old-growth forests are decreasing. In 6 states, the other, naturally regenerated forest areas have increased. In 5 states, old-growth forests remained unchanged.

Europe:

Other, naturally regenerated forest areas cover around 30 % (6,698,280 km^2, 2010) of Europe. From 2000 to 2010 the other naturally regenerated forest areas increased by around 0.6 % (42,763 km^2). In 27 states, old-growth forests are increasing. In 5 states, other naturally regenerated forest areas have decreased. In 5 states, old-growth forests remained unchanged.

2.1.5 Planted forest

Definition:

"Forest predominantly composed of trees established through planting and/or deliberate seeding.

1. In this context, predominantly means that the planted/seeded trees are expected to constitute more than 50 percent of the growing stock at maturity.
2. Includes coppice from trees that were originally planted or seeded. 3. Excludes self-sown trees of introduced species."

Source: Global Forest Resource Assessment 2010 – Terms and Definition

Underlying data bases:

FAO. 2010. Global forest resources assessment, 2010-Main report. FAO Forestry Paper 163. Rome, Italy. http://countrystat.org/for/en

Data quality / Type of data recording

„The country reports have been compiled by officially nominated country correspondents in collaboration with FAO staff. Prior to finalization, these reports were subject to validation by forestry authorities in the respective countries. The report contains data sources, original data and documentation of adjustments made to meet the definitions and classifications used in the global forest resources assessment."

Source: http://countrystat.org/for/cont/pages/page/metadata/en

Discrepancies / Missing data

Many discrepancies arise between Global Forest Resource Assessment 2000 (FAO) and the FAO Forestry Department 2010. Large amounts of non-existent data; for various states no values are available.

Trends

Asia/Australia:

Planted forests cover around 16 % (1,290,170 km^2, 2010) of the Asiatic / Australian forest area. From 2000 to 2010, planted forests increased by around 30% (298,510 km^2). Here, China plays a special role and is, with regard absolute number, ahead of all other.

America:

Planted forests cover slightly more than 2.5% (524.800 km², 2010) of America. From 2000 to 2010, planted forests increased by 30.42% (122.360 km²). In only one state (Jamaica), the forest area does decrease. In 19 states, planted forests increased. In 23 states, planted forest areas remained unchanged, or no data was available.

Africa:

For 7 states no figures are available, mainly for 2010.

Europe:

Planted forests cover around 3 % (548,360 km², 2010) of Europe. From 2000 to 2010, planted forests increased by around 114 % (292,520 km²). In 27 states, planted forests are increasing. In 3 states, planted forests decreased. In 1 state, old-growth forests remained unchanged.

2.1.6 Other land

Definition:

“All land that is not classified as Forest or Other wooded land.
1. Includes agricultural land, meadows and pastures, built-up areas, barren land, land under permanent ice, etc.

2. Includes all areas classified under the sub-category “Other land with tree cover”

Source: Global Forest Resource Assessment 2010 – Terms and Definition

Underlying databases:

FAO. 2010. Global forest resources assessment, 2010-Main report. FAO Forestry Paper 163. Rome, Italy. http://countrystat.org/for/en

Data quality / Type of data recording

“The country reports have been compiled by officially nominated country correspondents in collaboration with FAO staff. Prior to finalization, these reports were subject to validation by forestry authorities in the respective countries. The reports contains data sources, original data and documentation of adjustments made to meet the definitions and classifications used in the global forest resources assessment.“

Source: http://countrystat.org/for/cont/pages/page/metadata/en

Deviation / Gaps in Data bases

26 states in Europe

Trends

Asia:

Other areas cover around 70% (27,765,210 km², 2010) of Asia and Australia. From 2000 to 2010 other areas increased by around 5 % (1,381,260 km²). In 10 states, other areas are decreasing. In 22 states, other areas have increased. In 16 states, other areas decreased.

Africa:

Other areas cover 2010 around 65.73% (19488090 km^2) of Africa. From 2000 to 2010, other areas increased by around 2.45% (466710 km^2). In 10 states, other areas decreased. In 39 states, other areas have increased. In 8 states, other areas remained unchanged.

Europe:

Other areas cover around 4.7 % (993.000 km^2, 2010) of Europe. From 2000 to 2010, other areas decreased by around 1.1 % (11.190 km^2). In 12 states, other areas decreased. In 13 states, other areas have increased. In 5 states, other areas remained unchanged.

2.1.7 Agricultural areas

Definition:

“The sum of areas under

a) arable land - land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category;

b) permanent crops - land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees, which should be classified under „forest“); and

c) permanent meadows and pastures - land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).”

Source: http://faostat.fao.org/

Underlying data bases:

FAO Statistics Division 2012 – ResourceSTAT - Land-use

URL: http://faostat.fao.org/

Data quality / Type of data recording

Mainly FAO-assessment and manual estimation

Deviation / Gaps in Data bases

Various island countries, but also Turkey

Trends

Table 2: Land use change agricultural area

Agricultural area	Changes in km²	Changes in %
Argentina	117,300	9.11
Indonesia	79,230	17.35
Niger	67,820	18.33
Oman	7,630	71.11
Armenia	4,305	32.54
Laos	5,100	27.78
Australia	-464,710	-10.20
Mongolia	-146,700	-11.24
Iran	-143,690	-22.85
New Zeeland	-39,230	-25.45
Iran	-143,690	-22.85
Lithuania	-7,290	-21.33

Africa:

In 2009, the agriculturally used area in Africa covered around 39.16% of the total land area of the continent.

From 2000 to 2009, the agriculturally used area increased by around 3%. This represents a surface of 382,991 km². Out of 57 states, 38 experienced an increase of their of their agriculturally used area auf. In 17 states these areas decreased in size. 2 states had neither increase, nor decrease of their agriculturally used area.

America:

The agriculturally used area in America covered 2000 around 29,6% of the total land area of the continent.

From 2000 to 2009, the agriculturally used area decreased nearly unnoticeably by 0.06%. This represents a surface of 736 km². All 15 states experienced an increase of their agriculturally used area. In 16 states, these areas decreased in size. In 6 states sets of data were missing, or no changes took place.

Asia:

In 2009, the agriculturally used area in Asia and Australia represented 52.30 % of the total land surface. From 2000 to 2009, the agriculturally used area diminished slightly.

Europe:

In 2009, the agriculturally used area in Europe represented around 21% of the total land area of the continent. From 2000 to 2009, the agriculturally used area decreased by around 1.5 %. This represents a surface of 70.836 km^2. Out of 44 states, 30 experienced a decrease of their agriculturally used area. In 10 states, these surfaces increased. 4 states had neither increase, nor decrease of their agriculturally used area.

2.1.8 Arable land

Definition:

“Arable land is the land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Data for “Arable land” are not meant to indicate the amount of land that is potentially cultivable.” Source: http://faostat.fao.org/

Underlying data bases:

FAO Statistics Division 2012 – ResourceSTAT - Land-use

URL: http://faostat.fao.org/

Data quality / Type of data recording

Mainly FAO-assessment and manual estimation

Deviation / Gaps in Data bases

Various island countries, as well as small countries

Trends

Table 3: Land use change arable land

Arable Land	Changes in km ²	Changes in %
Nigeria	40,000	13.33
Ethiopia	39,480	39.48
Sudan	39,270	24.19
Oman	680	219.35
Granada	15	150
Sierra Leone	5,950	121.43
USA	-126,170	-7.19
China	-109,720	-9.07
India	-47,940	-2.95
New Zeeland	-10,290	-68.60
Bhutan	-550	-42.31
Colombia	-10,430	-37.01

Africa:

Arable land represents around 19.33% of their agriculturally used area (status 2009). As a proportion of the total land surface of Africa, arable land covers around 8%. From 2000 to 2009, arable land grew by around12.95% an. In absolute terms, this represents an area of 257,228 km². In total arable land increased in 34 of 57 states, whereas they decreased in 15 states. In 8 states, arable land surfaces remained unchanged.

America:

Arable land represents around 8% of the total land surface of Americas. From 2000 to 2009, arable land surface shrank by around 10%. In absolute terms, this represents an area von 325,705 km². In 15 states arable land surfaces have decreased. In 16 states, arable land increased.

Asia:

Arable land represents 25.29 % of their agriculturally used area (status 2009). As a proportion of the total land surface of Asia and Australia, arable land occupies around 10%. From 2000 to 2009, the surface covered by arable land diminished slightly.

Europe:

As a proportion of the total land surface in Europe, arable land covers around 12 %. From 2000 to 2009 arable land decreased by around 2 %. In absolute terms, this represents an area of 62,203 km^2. In total, tilled land surfaces decreased in 26 of 42 states. In 10 states, tilled land surfaces increased. In 6 states, arable land surfaces remained unchanged.

2.1.9 Permanent crops

Definition:

“Permanent crops is the land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees, which should be classified under „forest“). Permanent meadows and pastures are excluded from land under permanent crops.”

Source: http://faostat.fao.org/

Underlying data bases:

FAO Statistics Division 2012 – ResourceSTAT - Land-use

URL: http://faostat.fao.org/

Data quality / Type of data recording

Mainly FAO-assessment and manual estimation

Trends

Table 4: Land use change permanent crops

Permanent Crops	Changes in km^2	Changes in %
Indonesia	50,000	35.71
China	30,900	27.51
India	25,000	27.17
Sweden	60	200
Niger	400	200
Bangladesh	5,600	133.33
Brazil	-2,000	-2.67
Italy	-2,000	-7.13
Spain	-1,850	-3.77
Norway	-29	-57.45
Latvia	-60	-50
Slovakia	-230	-48.94

Africa:

Permanent crops accounted for around 2.48% of agriculturally used area in 2009. As a proportion of the total land surface of Africa, permanent crops occupy less than 1%. From 2000 to 2009, permanent crops grew by around 15.44%. In absolute terms, this represents a surface of 38,559 km^2. In total, permanent crops are increasing in size in 32 states. In 12 states, permanent crop areas decreased. In 13 states, these surfaces remained unchanged.

America:

As a proportion of the total land surface of America, permanent crops cover around 2.5%. From 2000 to 2009, permanent crops grew by around 4 %. In absolute terms, this represents a surface of 11,622 km^2. In 11 states, the surface covered by permanent crops increased. In 16 states, it decreased.

Europe:

As a proportion of the total land surface of Europe, permanent crops occupy less than 1%. From 2000 to 2009, permanent crops decreased by around 5.31 %. In absolute terms, this represents a surface of 8.664 km^2. In total, permanent crops decreased in 24 states. In 12 states, permanent crop-covered areas sank. In one country, these surfaces remained unchanged.

2.1.10 Permanent Meadows and Pastures

Definition:

"Permanent meadows and pastures is the land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land)."

Source: http://faostat.fao.org/

Underlying data bases:

FAO Statistics Division 2012 – ResourceSTAT - Land-use

URL: http://faostat.fao.org/

Data quality / Type of data recording

Mainly FAO-assessment and manual estimation

Deviation / Gaps in Data bases

In Africa for three states, as well as Tuvalu, Nauru, Pitcairn Islands

Trends

Table 5: Land use change permanent meadows and pastures

Permanent meadows and pastures	Changes in km ^{2}	Changes in %
Argentina	86,300	8.64
Niger	57,820	25.14
USA	16,690	0.71
Estonia	1,960	149.62
Oman	7,000	70.00
Cambodia	5,700	61.29
Australia	-463,820	-11.37
Iran	-170,760	-36.64
Mongolia	-144,560	-11.18
Denmark	-1,610	-44.97
Slovakia	-3,410	-39.42
Poland	-9,030	-22.12

Africa:

In 2009, land surfaces used as permanent pastures accounted for around 78.19% of the agriculturally used area in Africa. As a proportion of the total land surface of Africa, land surfaces used as permanent pastures occupy around 31%. From 2000 to 2009, land surfaces used as permanent pastures increased by less than 1%. In absolute terms, this represents a surface of 87,204 km^2.

Land surfaces used as permanent pastures grew in 13 states in total. In 7 states, land surfaces used as permanent pastures decreased. In 34 states, these surfaces remained unchanged.

America:

As a proportion of the total agriculturally used area of America, land surfaces used as permanent pastures occupy around 67.75%. From 2000 to 2009, land surfaces used as permanent pastures increased by around 0.6%. In absolute terms, this represents a surface of 2,993 km^2.

In total, land surfaces used as permanent pastures grew in 9 states. In 12 states, land surfaces used as permanent pastures decreased. In 14 states, these surfaces remained unchanged.

Asia:

Land surfaces used as permanent pastures account for around 71 % of agriculturally used areas in Asia and Australia. From 2000 to 2009, land surfaces used as permanent pastures diminished by 5.19 %.

Europe:

As a proportion of the total land surface of Europe, the land surface used as permanent pastures covers around 8 %. From 2000 to 2009, land surface used as permanent pastures sank by around 1 %. In absolute terms, this represents a surface of 21,001 km^2.

In total, the land surface used as permanent pastures sank in 20 states. In 17 states, the surface occupied by permanently used pastures increased. In 4 states these surfaces remained unchanged.

2.1.11 Other Land

Definition:

“Rest Land/Other land is the land not classified as Agricultural land and Forested Area. It includes built-up and related land, barren land, other wooded land, etc.” Source: http://faostat.fao.org/

“This includes all agricultural land, which is not specified previously. Such land may be potentially productive or not. Included are scattered farm buildings—that is, isolated buildings not belonging to closed villages or similar rural localities

or

includes Prairie Grasslands, Savannah/Portland and Chepperal/ Mediterranean Crops.” Source: UNITED NATIONS (1993) Readings in international environment statistics

Underlying data bases:

FAO Statistics Division 2012 – ResourceSTAT - Land-use URL: http://faostat.fao.org/ Data based on FAO definitions.

Data quality / Type of data recording

Exclusively manual estimation

Deviation / Gaps in Data bases

Great data deviations found for Rwanda; for 5 African states, no figures are available. Sets of data are missing for America; for 6 states, there is more than one value. No data for Marshall Islands, Micronesia.

Trends

Table 6: Land use change other land

Other Land	Change in km ^{2}	Change in %
Australia	511,670	32.42
Brazil	211,326	54.76
Mongolia	154,070	116.99
New Zeeland	39,116	147.50
Burundi	1,442	144.20
Slovakia	4,972	110.73
China	-192,138	-8.60
Argentina	-95,088	-8.41
Niger	-66,704	-7.55
Ruanda	-4,110	-90.73
Bhutan	-2,135	-69.39
Cuba	-5,974	-34.12

Africa:

In 2009, around 38.39% of the total land surface in Africa was covered by other used areas.

From 2000 to 2009, these areas sank by less than 1%. In absolute numbers, this represents a surface of 85,016 km². Out of 57 states, 26 states showed an increase of other areas. In 25 states these areas decreased in size. In 6 states there was no change.

America:

Around 29% of the total land surface in America is used for agricultural purposes not described in more detail.

From 2000 to 2009, this area increased by more than 3 %. In absolute numbers, this represents a surface of 363,412 km². Out of 35 states, 24 saw this area increase, whereas, it decreased in only 10.

Asia:

Around 27.83 % of the total land surface in Asia and Australia is covered by surfaces used for other purposes. From 2000 to 2009, this surface increased by 6 %.

Europe:

Around 33 % of the total land surface in Europe is covered by "other land".

From 2000 to 2009, the surface covered by „other land" grew by less than 1%. In absolute numbers, this represents a surface of 62,886 km². 24 states show an increase of other lands. In 15 states, these areas decreased in size. In 5 states, these areas remained the same.

2.1.12 Agricultural land irrigated

Definition:

"Area equipped to provide water (via irrigation) to crops. It includes areas equipped for full/partial control irrigation, equipped lowland areas, and areas equipped for spate irrigation." Source: AquaStat Database

"Agricultural area irrigated, part of the full or partial control irrigated agricultural land which is actually irrigated in a given year. Often, part of the equipped area is not irrigated for various reasons, such as lack of water, absence of farmers, land degradation, damage, organizational problems etc."

Source: Online resource: http://geodata.grid.unep.ch; http://faostat.fao.org/default.aspx

Underlying data bases:

Agricultural land irrigated: UNEP (2012): The UNEP Environmental Data Explorer, as compiled from Food and Agriculture Organization of the United Nations (FAO) - FAOStat. United Nations Environment Programme. http://geodata.grid.unep.ch

Area equipped for irrigation, total: AquaStat Database
http://www.fao.org/nr/water/aquastat/main/index.stm

Data quality / Type of data recording

Mainly AquaStat-estimations, data gathered in isolation (aggregated).

Deviation / Gaps in Data bases

The AquaStat-Data base provides data from 1998 to 2005. However, it only gives two values on various annual figures, mostly only one value for a specific year. The set of data produced by the Geodata Portal, which is based on FAO, is more uniform and provides no values for 5 states.

Africa:

No values have been furnished for 48 states. Great deviations in the case of Namibia.

Asia:

No values have been furnished for 47 states out of a total of 70.

Trends

Africa:

Irrigated agricultural surfaces account for less than 0,5% of the total land surface of Africa (status 2008). In Africa, these surfaces grew from 2002 to 2008 by around 21.13%: 5,684 km². In total, 7 states show an increased in irrigated agricultural surfaces within the period of time investigated. In 50 states, neither increases nor decreases were established.

Asia:

The surface diminished by 56 %.

2.1.13 Fallow land

Definition:

“Fallow land (temporary) is the cultivated land that is not seeded for one or more growing seasons. The maximum idle period is usually less than five years.

Land remaining fallow for two long may acquire characteristics requiring to be reclassified, such as „permanent meadows and pastures“ (if used for grazing), „forest or wooded land“ (if overgrown with trees), or „other land“ (if it becomes wasteland).” Source: http://faostat.fao.org/

Underlying data bases:

FAO Statistics Division 2012 – ResourceSTAT - Land-use

URL: http://faostat.fao.org/

Data quality / Type of data recording

Preponderantly: Data reported on country official publications or web sites (Official) or trade country files; Official data reported on FAO Questionnaires from countries

Manual Estimation

Deviation / Gaps in Data bases

Many important sets of data are missing, for 9 African states, more than one value is provided. The same applies to 6 states in the countries group America, where there is more than one value.

Trends.

Africa:

In view of the scarcity of data, is difficult to identify or describe a trend. 2 states experienced an increase in their fallow land areas, whereas 6 saw such surfaces decreasing. In one state, there were no changes (2002 to 2008) could be observed.

America:

In view of the scarcity of data, is difficult to identify or describe a trend. According to statistics, the total fallow land sank by 8,750km², which corresponds to around 50%.

Asia:

In view of the scarcity of data, is difficult to identify or describe a trend. In total, this surface sank by around 32 %.

Europe:

Fallow land surface decreased by around 29 % since 2003 and sank to an area covering 107,921 km², which represents a proportion of around 2 % to the total land surface. In 12 states, fallow land surfaces have increased since 2003. 18 states show an increase in their fallow land areas. 2 states show neither increase, nor decrease in their fallow land areas.

2.2 Other Land Use and Driving-Forces Parameters

2.2.1 Urban population

Definition:

"Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects."

Source: http://data.worldbank.org/indicator/SP.URB.TOTL

Underlying data bases:

United Nations World Urbanization Prospects

Source: http://data.worldbank.org/indicator/SP.URB.TOTL

Data quality / Type of data recording

World Bank population estimates

Source: http://data.worldbank.org/indicator/SP.URB.TOTL

Deviation / Gaps in Data bases

Mayotte, Reunion, Saint Helena,

Asia: No data is available for 8 states.

Trends

The set of data on "urban population" can be seen as an indicator for the changes occurring in human settlements.

Table 7: Changes in urban population

Urban Population	Change per Head of population	Change in %
China	148,869,571	32.93
India	71,041,667	25.24
Indonesia	39,184,621	43.72
Qatar	1,124,106	200.44
VAE	3,499,062	148.26
Bhutan	122,045	84.11
Russia	-4,192,402	-3.90
Ukraine	-1,759,047	-5.33
Poland	-355,225	-1.50
Latvia	-85,663	-5.30
Lithuania	-113,208	-4.83
Bulgaria	-144,776	-2.61

Africa:

From 2000 to 2010, urban population increased around 40.62%. In 2010, 408,959,131 people in total were living in urban spaces. This represents 40% of the total population. In 2000, this figure was still at 36%.

In relation to rural population, the increased population figure is greater in urban spaces (around 21 %).

America:

From 2000 to 2010, urban population increased on the whole of the continent by around 17 %. In 2010, 748,690,650 people in total were living in urban spaces. This represents around 80 % of the total population. In 2000, this number was still around 73 %. On the whole of the continent, rural population is decreasing compared to the constantly growing urban population. No data points out to a decrease in urban population.

Asia:

From 2000 to 2010, urban population increased by 22,4 % an. In 2010, a total of 1,708,226,749 people were living in Asia and Australian in urban spaces. This corresponds to 42.40% of the total population. In 2000, this figure was at 35.90 %.

Europe:

In 2000, Europe's "urban population" totaled 574,815,830 persons. In 2010, urban population had already reached 602,859,102 people, which represents an increase of 5 % (+28,043,272). This brings the proportion of urban population in 2010 to around 72 % of the total population. In 38 states, "urban population" increased, whereas it decreased in 12 states.

2.2.2 Rural Population

Definition:

Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects. Source: http://data.worldbank.org/indicator/SP.URB.TOTL

Underlying data bases:

United Nations World Urbanization Prospects

Source: http://data.worldbank.org/indicator/SP.URB.TOTL

Data quality / Type of data recording

World Bank population estimates

Source: http://data.worldbank.org/indicator/SP.URB.TOTL

Deviation / Gaps in Data bases

Only for some island states, there is no data are available.

Trends

Table 8: Changes in rural population

Rural Population	Change per Head of population	Change in %
India	83,973,333	11.43
Pakistan	12,823,007	13.28
Ethiopia	12,543,631	22.48
VAE	979,137	145.39
Niger	3,768,468	41.17
Iraq	2,933,364	37.47
China	-73,215,059	-3.90
Indonesia	-12,709,095	-10.27
Brazil	-6,474,199	-19.74
Venezuela	-773,993	.30.91
Netherlands	-854,031	-23.11
Brazil	-6,474,199	-19.74

Africa:

The set of data on “rural population“ can be considered as an indicator for the changes in settlement areas. From 2000 to 2010, rural population numbers by around 17.95%. In 2010, 611,437,006 people in total were living in the countryside. This represents around 60% of the total population. In 2000 this figure was still 64%.

America:

From 2000 to 2010, rural population decreased by around 5.6%. In 2010, 183,354,254 people in total were living in the countryside. This represents around 20% of the total population. In 2000 this figure was still 193,667,307 people, this means around 23%.

Asia:

From 2000 to 2010 rural population increased by around 2%. In 2010, 2,327,867,861 people in total were living in the countryside. This represents around 58% of the total population. In 2000 this figure was still around 62% of the total population.

Europe:

In 2000, “rural population” was of 238,827,402 in Europe and decreased to 233,571,220 in 2010. This represents a decrease of 5,256,182 (-2%).

This brings the proportion of the rural population in 2010 to around 28 % of the “total population”.

In 20 states, rural population increased.

In 30 states, rural population decreased.

2.2.3 Urban and Built-up Areas

Definition:

For 1992-93:

“Urban and built-up areas are covered by buildings and other man-made structures. The classifications reported here are published using the International Geosphere-Biosphere Programme (IGBP) definitions. The area of urban and built-up areas is determined by the Global Land Cover Characteristics (GLCC) project.” Source: earthtrends.wri.org

For 2000:

“Urban and built-up areas are covered by buildings and other man-made structures. The area of Urban and built-up areas is determined by the Global Land Cover (GLC2000) project. The project uses a framework of temporal and spatial patterns of satellite data, in conjunction with ancillary data, to assign a vegetation classification to each pixel.” Source: earthtrends.wri.org

“Urban or Built-up Land is comprised of areas of intensive use with much of the land covered by structures. Included in this category are cities, towns, villages, strip developments along highways, transportation, power, and communications facilities, and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas.” Source: United Nations (FAO) Land Cover Classification System (LCCS)

Underlying data bases:

Global Land Cover 2000 database. European Commission, Joint Research Centre, 2003.

Data quality / Type of data recording

Urban and built-up areas (1992-93 data): The GLCC describes the method used to classify vegetation types as a „multitemporal unsupervised classification of NDVI data with post-classification refinement using multi-source earth science data.“ NDVI data are a measure of „greenness“ derived from satellite data. The satellite data in this study were from the Advanced Very High Resolution Radiometer (AVHRR), and have a resolution of 1 X 1 km. The other data sets employed were a digital elevation model to help model ecological factors that govern natural vegetation distribution, Eco regions data to help determine where vegetation would be stratified by seasonal impacts, and maps of soils, vegetation, and land cover to help with the post-classification refinement.

Urban and built-up areas (2000 data): The current analysis from the GLC2000 dataset is based on the interpretation of 1-km SPOT4 satellite data from 2000. After the images were collected, a partnership of 21 institutions from around the world worked to classify the imagery based on the Food and Agriculture Organization of the United Nations (FAO) Land Cover Classification System (LCCS). Their results were tested in the field to ensure accuracy of the classification scheme.

Deviation / Gaps in Data bases

"The calculations for urban and built-up areas for 2000 should not be compared to the previous calculations for urban and built-up areas for 1992-1993 (GLCCD v.2). Although the methods WRI used to calculate total urban area by country are the same for the two tables, the data from which the calculations were derived are different. The previous analysis from the GLCCD was derived from 1-km Advanced Very High Resolution Radiometer (AVHRR) data spanning a 12-month period (April 1992-March 1993). The current analysis from the GLC2000 dataset was derived from interpretation of 1-km SPOT4 satellite data from 2000. Many differences also exist in the interpretation methodology and classification systems used to derive the datasets.

Given the relatively high level of potential for misclassification, the area classified as urban and built-up land should be treated as an estimate rather than an exact interpretation of the earth's surface." (Global Land Cover 2000 database. European Commission, Joint Research Centre, 2003.)

Africa:

In 15 states sets of data are missing. (For example Côte d'Ivoire, Equatorial Guinea, Liberia, Madagascar)

America:

In 16 states sets of data are missing. (Amongst others Turks and Caicos Islands, Greenland, Belize)

Asia:

In the oceanic island states, sets of data are missing.

Trends

Africa:

From 1992-93 to 2000, settlement areas in Africa grew by around 282.68%. This represents an increased area of 20,941 km^2. In 2000 settlement areas covered around 0.09% of African land surface. In 34 states, settlement areas increased. 10 states have decreasing settlement areas. In 9 states, no changes in settlement areas were reported.

America:

From 1992-93 to 2000, settlement areas in America grew by around 0,42 %. This represents an increased area of 425 km^2. In 34 states settlement areas are increasing. 10 states have decreasing settlement areas. In 9 states, no changes in settlement areas were reported.

Asia:

From 1992-93 to 2000 settlement areas in Asia and Australia grew by 18,83 % (+11.523 km^2). In 2000 settlement areas covered around 0.16% of the Asiatic/Australian land surface. In 20 states settlement areas are increasing. 24 states have decreasing settlement areas. In 6 states, this means a decrease of 100 %.

Europe:

The total settlement areas covered less than 0,5 % (96.295 km^2) of the land surfaces in 1992 in Europe. From 1992-2000 areas built-up and habited by humans sank by around 3 % and sank to an area of 93,030 km^2. In 8 states this area sank. In 31 states, on the contrary, the settlement area increased.

2.2.4 Urban Area

a) urban area, circa 1995 (country LECZ)

b) sum of the land area of all urban extents (city size)

Definition:

- For country LECZ:

Dataset of zonal statistics summarizing the urban, rural and total land area, and urban, rural & total 1990, 1995 & 2000 population for each country and for the portion of each country intersecting the low elevation coastal zone (LECZ).

- For city size:

Dataset of zonal statistics summarizing the number of urban extents, 2000 population, land area by city size for each country and for the portion of each country intersecting the low elevation coastal zone.

Source: http://sedac.ciesin.columbia.edu

The sum of all of the urban spatial areas by sq.km.

Underlying data bases:

Center for International Earth Science Information Network (CIESIN), Columbia University. Low Elevation Coastal Zone (LECZ) Urban-Rural Estimates, Global Rural-Urban Mapping Project (GRUMP), Alpha Version. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Source: **http://sedac.ciesin.columbia.edu/data/set/grump-v1-urban-extents**

Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IPFRI); the World Bank; and Centro International de Agricultural Tropical (CIAT), 2004. Global Rural-Urban Mapping Project (GRUMP), version 1: GPW with Urban Reallocation (GPW-UR) Population grids. Palisades, NY: CIESIN, Columbia University.

Data quality / Type of data recording

“The Global Rural-Urban Mapping Project, Version 1 (GRUMPv1) consists of estimates of human population for the years 1990, 1995, and 2000 by 30 arc-second (1km) grid. The urban extent grids distinguish urban and rural areas based on a combination of population counts (persons), settlement points, and the presence of Nighttime Lights. Areas are defined as urban where contiguous lighted cells from the Nighttime Lights or approximated urban extents based on buffered settlement points for which the total population is greater than 5,000 persons. This dataset is produced by the Columbia University Center for International Earth Science Information Network (CIESIN) in collaboration with the International Food Policy Research Institute (IFPRI), The World Bank, and Centro Internacional de Agricultura Tropical (CIAT)”

The spatial detail of census data varied greatly between countries and 1km resolution was considered the highest resolution that could be supported globally."

Source: http://sedac.ciesin.columbia.edu/data/set/grump-v1-urban-extents

Deviation / Gaps in Data Bases

a) The set of data on "urban area in square kilometers for the country, circa 1995 (country LECZ)" has smaller values than the set of data on the "sum of the land area (sq. km) of all urban extents for the country (city size)".

b) It is not obvious, for which year the data refer to. There are high discrepancies to the data sets of „urban area in square kilometers for the country, circa 1995 (country LECZ)" and „sum of the land area (sq. km) of all urban extents for the country (city size)"

Trends

Africa:

a) Increase in settlement areas by around 6.65%. The first data set was collected in 1995. The second set probably in 2000. From 1995 to 2000, settlement areas increased by around 6.65% (13,687 km²).

   In 55 states settlement areas have grown. No decrease in settlement areas has been reported in any state. In 2 states no data are available.

b) Increase in Settlement areas by around 6,65%. The first data set was probably collected in 2000. For the second set, the collection year is unknown. From 2000 to ? settlement areas grew by around 14.63% (32,126 km²).

   In 40 states settlement areas have grown. In 13 states, settlement areas are decreasing. In 4 states no data are available.

America:

a) The first data set was collected in 1995. The second set probably in 2000. From 1995 to 2000, settlement areas grew by around 6.52% (86,543 km²).

   In 55 states settlement areas increased. In only one state (Aruba) a diminution in settlement areas has been recorded. For two states (Monserrat, Turks and Caicos Islands) no change can be detected.

b) Decrease of Settlement areas by around 1,13 %. The first data set was probably collected in 2000. The collection year of the second set of data is unknown.

   In 28 states settlement areas increased. In 14 states, settlement areas are decreasing. In 2 states no data are available.

Asia:

Settlement areas in Asia and Australia increased by 18.68 %. Period of time is unknown. The first data set was collected in 1995. The second set probably in 2000. The increased area is of 224,667 km². In 50 states settlement areas increased. In 5 states there was a decrease in settlement areas

Europe:

In 1995 total settlement areas covered around 3.5 % (780,106 km²) of the land surfaces in Europe. From 1995-2005 the surface built-up and populated by humans grew by around 8 % (67,675km²) and increased to an area of 847,781 km². In 4 states sank this area. In 42 states, built-up areas increased.

2.2.5 Land under Roads

Definition:

"Part of total land under transport and communication facilities which is used by public roads, including motorways, and their auxiliary services. Included are pavements, public parking lots along roads, and similar spaces."

Source: UNITED NATIONS (1993) Readings in international environment statistics

"Total road network includes motorways, highways, and main or national roads, secondary or regional roads, and all other roads in a country."

Source: http://geodata.grid.unep.ch/mod_metadata/metadata.php

Underlying data bases:

Source: International Road Federation World Road Statistics

Science Information Network (CIESIN) at Columbia University under its contract to manage the NASA Socioeconomic Data and Applications Center (SEDAC),

Source: http://www.ciesin.columbia.edu/confluence/display/roads/4.+Download+Data

Data quality / Type of data recording

Type of data collection is unknown. Data quality is difficult to evaluate.

Discrepancies / Gaps in Data bases

Africa:

In view of the many missing sets of data, deviations are difficult to detect. Ethiopia, Egypt and Madagascar, have the greatest data discrepancies, bringing inaccuracies into the description of trends.

Both sources provide no homogenous data series. For some states, there are either no values available or there is just one figure representing various annual values. Comparability between the states can therefore is not possible.

In total, there are no figures for 6 states. 25 states only have one value and could not be taken into account in the detection of a trend.

Furthermore, the definitions of the UNO and the World Bank vary from one another.

Trends

Africa:

In total 26 states, for which there were at least 2 values for different years, were observed in order to detect trends. The period of time under observation is varying. 20 of 26 states show an increase in road length. In 4 states, road length decreased and in 2 states, there were no changes within the observed period of time.

America:

In total for the detection of the trend, the states observed were those with at least 2 values for the period of time from 2000 to 2005. It can be noted that in all states, apart from Nicaragua, road length is increasing.

Asia:

In total for the detection of the trend 26 states were observed, which had at least 2 values for various years. The observed period of time varies. 20 out of 26 states show an increase in road length. In 4 states, road length decreased and in 2 states, no changes were recorded for the observed period of time. With a total length of 503,253 km road-building in the countries India and China represent nearly 86 % of road-building in Asia and Australia. There has been at least temporary decrease in road length in: Iran, Azerbaijan, North Korea.

Europe:

In 2008, 3,532,696.00 km² were sealed off by road building in Europe. This represents a proportion of the total area in Europe of around 15 %. The road-covered area increased from 2000 by 173,616 km² (around +5.1 %). In 26 states, the area covered by road is increasing.

2.2.6 Land under Rails

Definition:

"Part of total land for transport and communication facilities which is used by public railways as well as by private rail systems operating on a commercial basis. Included is land used for their auxiliary services, such as stations, related administrative buildings, storage yards, installations for repair and maintenance of equipment, and the like."

Source: UNITED NATIONS (1993) Readings in international environment statistics

Rail lines are the length of railway route available for train service, irrespective of the number of parallel tracks.

Source: World Bank, Transportation, Water, and Information and Communications Technologies Department, Transport Division.

Underlying data bases:

World Bank, Transportation, Water, and Information and Communications Technologies Department, Transport Division.

URL: http://data.worldbank.org/indicator/IS.RRS.TOTL.KM

Deviation / Gaps in Data bases

Africa:

For 29 states, no data is available. For 5 states, there is only one value available.

Trends

Africa:

In total 22 states were observed for the detection of the trend, which have at least 2 values for different years. The observed period of time varies. 6 out of 22 states show an increase in track length. In 11 states, road length decreased and in 5 states, no changes were reported in the observed period of time.

America:

In total 9 states were studied for the detection of the trend, which have at least 2 values for different years. The observed period of time varies. In five out of nine observed data sets, track length decreased, in four cases, it increased. In the US, the network increased from 2000 to 2005, then it shrank slightly.

Europe:

In 2000, 347,650.00 km² of the total areas in Europe were covered by tracks. In 2008, this figure was still 347,213.00 km², which means a decrease by 9,353 km². Thus the share of tracks represented around 1.5 % of the total area in Europe.

Asia:

In 20 states, the area covered by tracks increases. In one state, this area retained its size. In 15 countries, this area diminished.

2.2.7 Mineral Extraction of Iron, Bauxite, Gold, Phosphate, Steam Coal, Coking Coal, Uranium

Definition

The production of minerals, from underground or surface workings.

Definition in reference to Land Cover and Land use:

Land used for Mining:

Mineral extraction from underground workings. The area covered as a form of land use is the surface area occupied by mining buildings, pit-head works, waste heaps, etc. Excludes opencast mineral extraction.

Land used for quarrying:

Mineral extraction from surface workings. A superficial layer of the land is completely removed. There may or may not be restoration of the former ecosystem. As a form of land use, includes types of surface mineral extraction that are commonly: called ‚mining' e.g. bauxite, opencast coal workings. Includes the extraction of soil or turf.

Source: FAO (Hrsg.) Young A.(1994) TOWARDS AN INTERNATIONAL CLASSIFICATION OF LAND USE

Underlying data bases:

International Organizing Committee for the World Mining Congresses. World Mining Report 2009 and 2011.

Data quality / Type of data recording

Adequate balance between reported and evaluated values. The data from the World Mining Reports refer on Evaluation of the US Geological Survey (former US Bureau of Mines), US Bureau of Mines/nunmehr US Geological Survey, National statistics/Landesstatistiken, Metallgesellschaften, World Mineral Statistics, Mining Annual Review, Öldorado (ESSO), World Oil, Intern. Petroleum Encyclopedia, IAEA, OECD and ECE, Oil & Gas Journal, IEA, International Consultative Group, BP plc, British Geological Survey, International Chromium Development Association.

Deviation / Gaps in Data bases

The data is based on the exploitation of minerals from underground and open pit mines and not on land use

Trends

The trend analysis for the promotion and exploitation of selected minerals and products relating to the years 2003 to 2010

Table 9: Changes in exploration and production of selected raw materials according to country group

2003-2009	Africa	America	Asia/Australia
Exploitation			
Iron	+38.2%	+24%	+183%
Bauxite	+3.3%	+133%	+64.1%
Phosphate	+9.9%	-10%	+92.5%
Gold	-19.9%	-2%	+8%
Oil sands		+27%	
Production			
Steam coal	+3.4%	+4%	+64.3%
Coking coal	+23.2%	+15%	+87.6%
Uranium	+58.7%		+100.8%
Aluminium	-17.4%		

In the period under consideration, the increase of mining / production in Asia is not worthy. The growing global demand for energy shows is reflected in the high increase in the production of energy sources. But also iron, bauxite or aluminium, which are needed in the sector building and technology show high increases. The increase in the exploitation of phosphorus reflects a global intensivation in agriculture, because phosphorus is increasingly used in developing countries as essential nutrient.

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2.3 Summary

To summarise, the following states showing the greatest land-use change in absolute terms.

Table 10: Ranking of countries with the highest Land use change Part 1

Rank	Frequency under the TOP 10 for increase per category	
1	China	9
2	United States of America	9
3	Brazil	8
4	India	8
5	Indonesia	7
6	Canada	5
7	France	5
8	Spain	5
9	Sudan	5
10	Algeria	4
11	Iran (Islamic Republic of)	4
12	Kazakhstan	4
13	Mali	4
14	Mexico	4
15	Russian Federation	4
16	Viet Nam	4
17	Argentina	3
18	Australia	3
19	Bangladesh	3
20	Ethiopia	3

The Ranking takes into account 18 categories from the fields of agriculture, forestry, settlement areas and infrastructure measures. Population growth, waste-disposal and mineral extractions are not included in the computations.

China has by far the greatest increases in various land use categories, followed by the United States, Brazil and India

The largest decreases in agriculture and forestry categories are found in Indonesia, Russia and Australia.

Table 11: Ranking of countries with the highest Land use change Part 2

Rank	Frequency under the TOP 10 for increase per category	
1	Indonesia	7
2	Russian Federation	7
3	Australia	6
4	Brazil	6
5	China	5
6	Colombia	5
7	India	5
8	Poland	5
9	United Republic of Tanzania	5
10	Kazakhstan	4
11	Nigeria	4
12	Spain	4
13	United States of America	4
14	Argentina	3
15	Bolivia	3
16	Germany	3
17	Iran (Islamic Republic of)	3
18	Italy	3
19	Kenya	3
20	Mongolia	3

The Ranking takes into account 18 categories from the fields of agriculture, forestry, settlement areas and infrastructure measures. Population growth, waste-disposal and mineral extractions are not included in the computations.

The next states with large increases and decreases, and thus massive land-use changes under consideration are Spain, Kazakhstan and Sudan.

Table 12: Ranking of countries with the highest Land use change Part 3

Rank	Sum out of increase and decrease	
1	**Brazil**	**14**
2	**China**	**14**
3	**Indonesia**	**14**
4	**India**	**13**
5	**United States of America**	**13**
6	**Russian Federation**	**11**
7	**Australia**	**9**
8	**Spain**	**9**
9	**Kazakhstan**	**8**
10	**Sudan**	**8**
11	Canada	7
12	France	7
13	Iran (Islamic Republic of)	7
14	Nigeria	7
15	Viet Nam	7
16	Argentina	6
17	Colombia	6
18	Italy	6
19	Mali	6
20	Mexico	6

The Ranking takes into account 18 categories from the fields of agriculture, forestry, settlement areas and infrastructure measures. Population growth, waste-disposal and mineral extractions are not included in the computations.

The states, whose performance stands out, hold together 47% of the total land surface of the statistically listed states, so that the relevance of land-use change in these states is significant.

In considering the categories waste disposal, raw-materials exploitation and Population development it becomes evident that their size has no influence with regard the surface. However, all categories have a great influence on surface utilisation. Here are settlement areas, open-mine surfaces, dumping grounds sites and of course also landfills the logical consequence. These categories are considered separately from those, whose size has a direct relation to land-use.

China, followed by India and Brazil are conspicuous because they have the greatest increase. But also Kazakhstan shows a similar changing pattern as Brazil.

Table 13: Ranking of countries with the highest changes in other categories Part 1

Rank	Frequency under the TOP 10 for increase per category	
1	**China**	**10**
2	**India**	**9**
3	**Brazil**	**8**
4	**Kazakhstan**	**8**
5	**Australia**	**5**
6	**United States of America**	**5**
7	**Indonesia**	**4**
8	**Iran (Islamic Republic of)**	**4**
9	**Mexico**	**4**
10	**Bangladesh**	**3**
11	Colombia	3
12	Nigeria	3
13	Pakistan	3
14	Russian Federation	3
15	South Africa	3
16	Turkey	3
17	Bosnia and Herzegovina	2
18	Democratic Republic of the Congo	2
19	Egypt	2
20	Ethiopia	2

The Ranking takes into account 12 categories from the fields of population development and Mineral Extraction. Waste disposal is not included in the computations. The categories population development and mineral extraction are considered as indicators or driving force for land-use changes.
The more often a state is found among the Top 10, the greater the likelihood that population development and mineral extraction influence land-use changes

The greatest decreases, however, are found in Russia, Venezuela and Rumania. However, these countries left no significant mark in other categories.

Table 14: Ranking of countries with the highest changes in other categories Part 2

Rank	Frequency under the TOP 10 for decrease per category	
1	**Russian Federation**	**6**
2	**Venezuela (Bolivarian Republic of)**	**6**
3	**Romania**	**5**
4	**Ukraine**	**5**
5	**United States of America**	**5**
6	**Canada**	**4**
7	**Germany**	**4**
8	**Australia**	**3**
9	**Brazil**	**3**
10	**Bulgaria**	**3**
11	Czech Republic	3
12	Hungary	3
13	Indonesia	3
14	Poland	3
15	South Africa	3
16	France	2
17	Guinea	2
18	Iran (Islamic Republic of)	2
19	Jamaica	2
20	Japan	2

The Ranking takes into account 12 categories from the fields of population development and Mineral Extraction. Waste disposal is not included in the computations. The categories population development and mineral extraction are considered as indicators or driving force for land-use changes.

The more often a state is found among the Top 10, the greater the likelihood that population development and mineral extraction influence land-use changes

In total, on the other hand, Brazil, China, India and the US turned appeared as the countries with the greatest changes in the categories not directly area-related.

Table 15: Total Ranking of countries with the highest changes in other categories

Rank	Sum of increase and decrease	
1	**Brazil**	**11**
2	**China**	**11**
3	**India**	**10**
4	**United States of America**	**10**
5	**Russian Federation**	**9**
6	**Australia**	**8**
7	**Kazakhstan**	**8**
8	**Indonesia**	**7**
9	**Ukraine**	**7**
10	**Venezuela (Bolivarian Republic of)**	**7**
11	Iran (Islamic Republic of)	6
12	South Africa	6
13	Canada	5
14	Romania	5
15	Colombia	4
16	Germany	4
17	Mexico	4
18	Turkey	4
19	Bangladesh	3
20	Bulgaria	3

The Ranking takes into account 12 categories from the fields of population development and Mineral Extraction. Waste disposal is not included in the computations. The categories population development and mineral extraction are considered as indicators or driving force for land-use changes.

The more often a state is found among the Top 10, the greater the likelihood that population development and mineral extraction influence land-use changes.

Because of other factors, as well as on the basis of this land-use change analysis, the following countries were selected in AP 1.4 for further consideration:

Argentina, Australia, Brazil, India, Indonesia, Kazakhstan, Nigeria, Poland, Russia, Sudan and the USA.

3 Analysis of a Selection of Land-Use Categories

In what follows, the parameters oft he changes reviewed in chapter 1, which are occurring in the countries Argentina, Australia, Brazil, Kazakhstan, India, Indonesia, Nigeria, Poland, Russia, Sudan and the United states of America (USA) will be considered more intensively.

3.1 Analysis of Global Land Use in its Various Expressions

3.1.1 Forested Areas

All countries studied, with the exception of India and Poland experienced a diminution of their forest area. In the absolute, the forest area of Brazil has shrunk by a total of 264,210 km^2 within 10 years. Even though Nigeria shows the strongest reduction in percentage terms in relation to forest area standing in the year 2000, in absolute terms, however, this surface is of 40,960 km^2 . The losses of the Indonesian forest area, which is of 49.770 km^2, and of Australia with 56.200 km^2, are also of this order of magnitude.

The order of magnitude of the reforestation in India and the USA, which is of 30,440 km^2 and 38,270 km^2 respectively, is noteworthy.

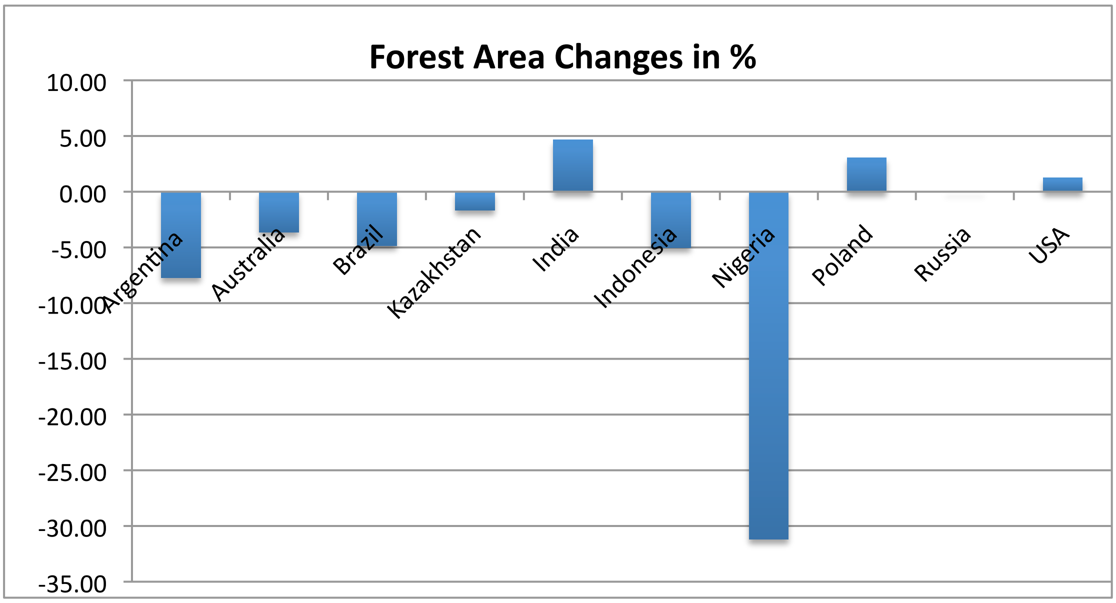

Figure 7: Changes Forested area in %

3.1.2 Agricultural area

The absolute greatest losses in agriculturally used area took place in Australia with a surface loss of 464.710 km^2, as well as in the USA, with a total of 109,480 km^2. But also Poland lost 22,940 km^2, which corresponds to around the same loss as that of Nigeria, which is of 26,500 km^2. Not only Indonesia, but also Argentina, conversely, generated new agriculturally used areas in the orders of magnitude of 79,230 km^2 and 117,300 km^2.

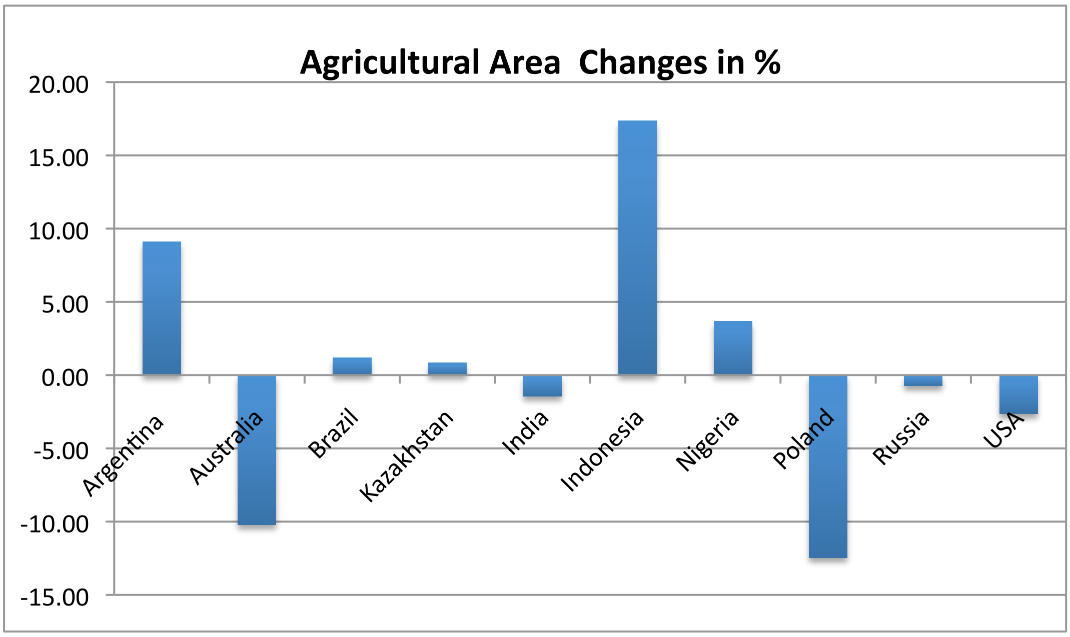

Figure 8: Changes Agriculturally used area in%

3.1.3 Permanent Meadows and Pasture

The field of permanent pasture is a sub-category of agriculturally used areas, here however, these changes are particularly relevant fort he climate, because permanent pasture, of all agricultural uses, is the activity that binds the largest volume carbon, and large amounts of CO_2 are released in case of upheaval.

In absolute terms, the greatest losses of permanent pasture were found to have occurred in Australia, with an area of 463,820 km^2. This represents nearly the same losses in agriculturally used land, as was presented in the previous chapter. A similar picture arises in Nigeria, where the proportion of the decrease of permanent pasture is slightly more than 64% of the decrease of agriculturally used land. In all other countries studied here, the diminutions are not particularly conspicuous. Increases in permanent pasture have occurred mainly in Argentina with 86,300 km^2, which corresponds to an increase of 73% of agriculturally used surface. Russia and the US experienced slight increases of around 10,960 km^2 and 16,690 km^2.

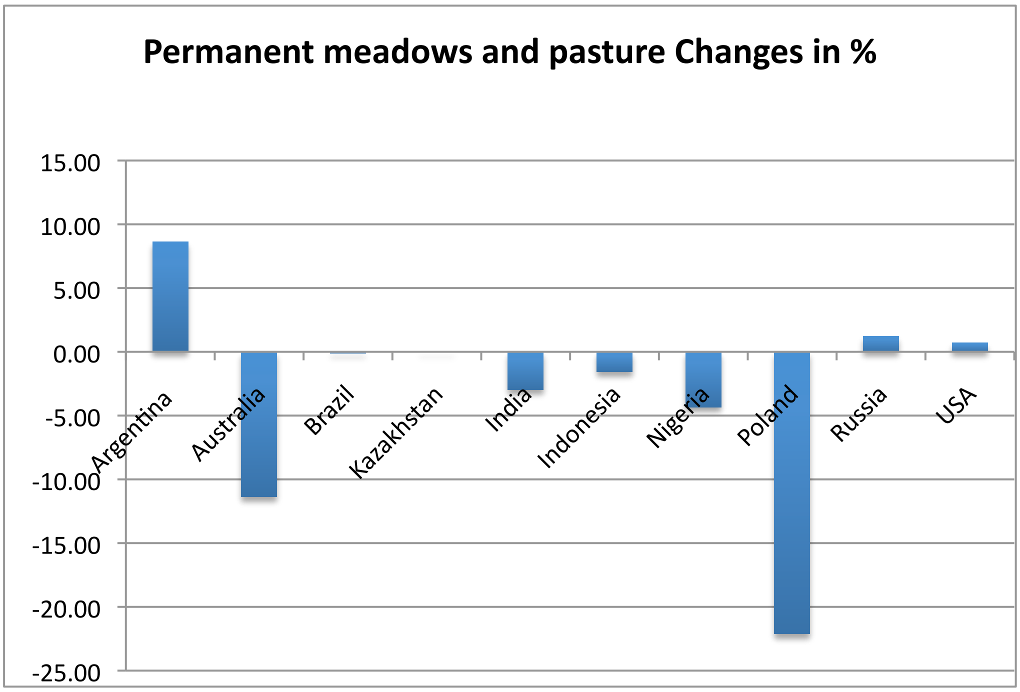

Figure 9 Changes Permanent pasture

3.1.4 Other Land

As explained in Chapter 1.2 about AP 1.1, the category "other land" includes a large number of various sub-categories. In general, the proportion of the surface of this category is increasing. This is also the case in Australia and Brazil. However, the countries, in which this category is strongly diminishing are of interest. In this case, these would be Argentina, Indonesia and Kazakhstan. These effects will be described in more details during the individual reviews oft he countries.

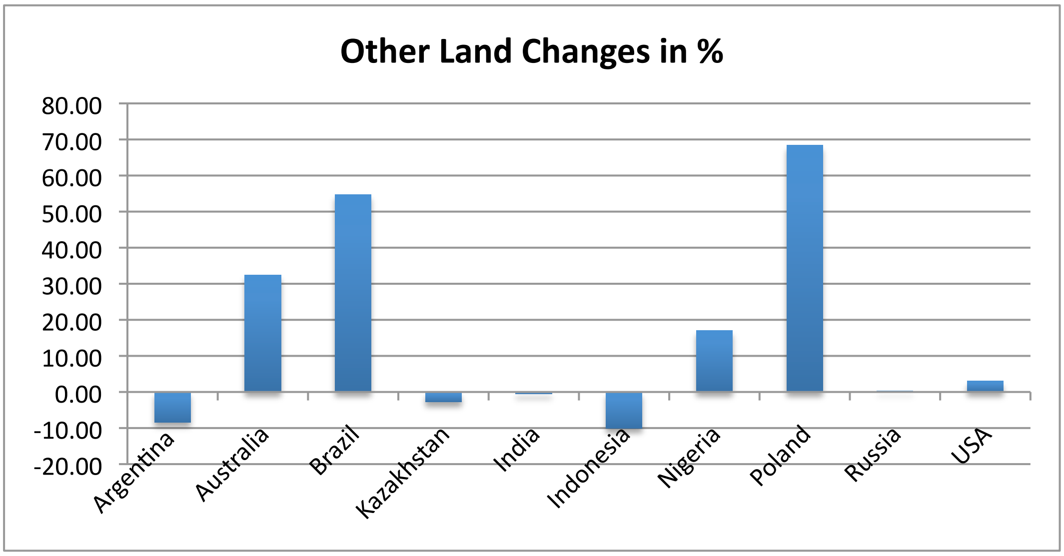

Figure 10 Changes Other Land

3.1.5 Total population

The population grew first and foremost in Nigeria and India quite distinctly. Surprisingly, Australia's population also grew. But also the USA was able to report medium-size increases. Not only Poland but also Russia reported decreases of the total population.

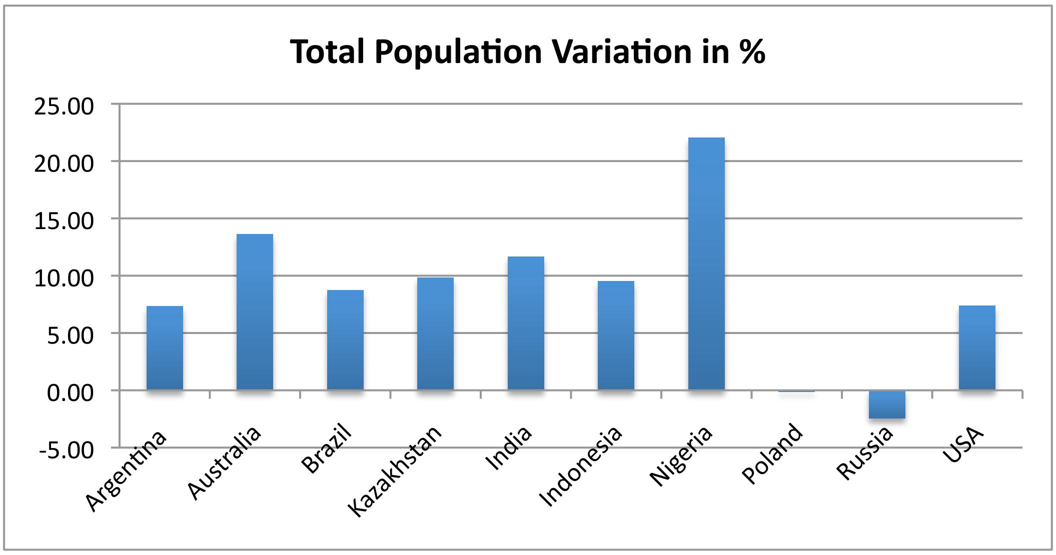

Figure 11: Changes in Population

4 Analysis of Individual States

4.1 Argentina

In Argentina, there is a clear broadening of agricultural land by over 9 %, as well as an increase of permanent pasture slightly below 9 %. Forested area, conversely, with 7,7 % decreases intensively. This also concerns the category other land with over 8% within the period studied. Argentina's population increases by over 7 %.

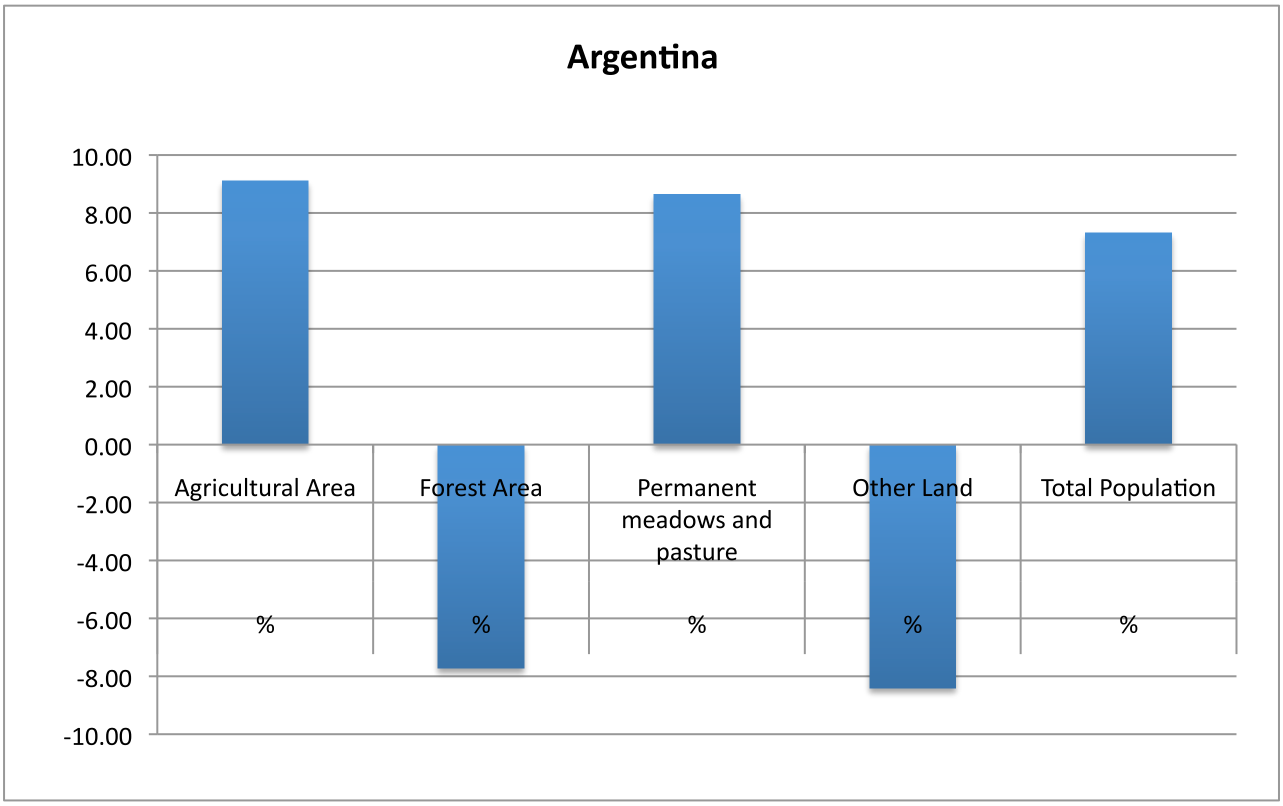

Figure 12: Land-use changes and Population development in Argentina

The increase in agricultural land, which has been occurring since 2003, can be clearly observed. While in the years before then, only slight increases could be detected, this area has widened within only 4 years by around 150,000. This trend has only been interrupted in 2009 for a short while, after which it continued. Like in Brazil, soya and wheat crops are strongly increasing in Argentina.

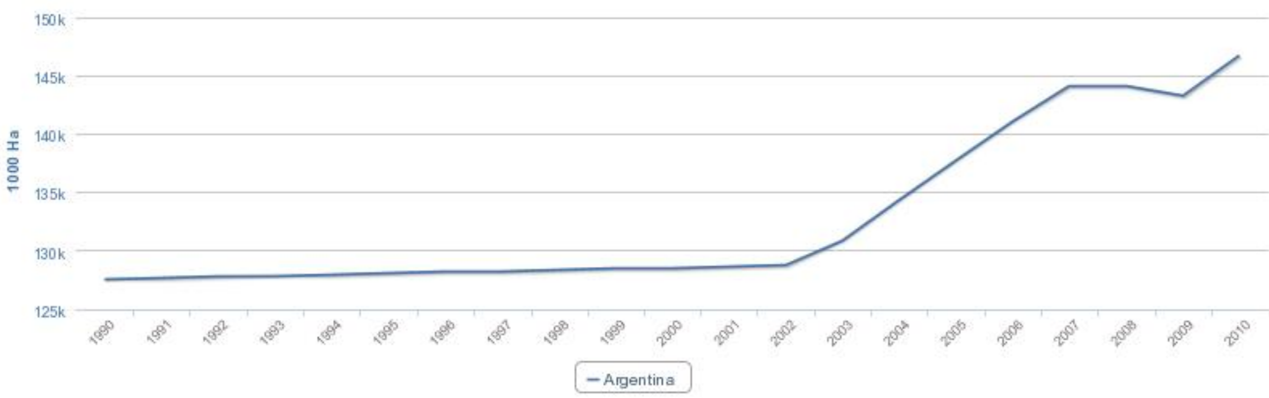

Figure 13: Agriculturally used area Argentina

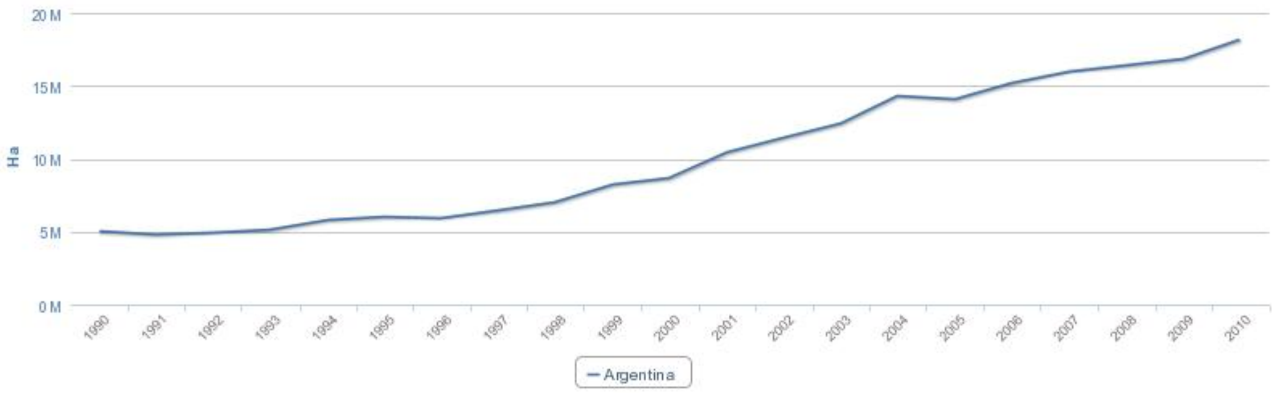

Figure 14: Soybean cultivation Argentina

While a part of the soya crops are exported to Europe as well as to China, a given proportion remains is kept in the country, in order to fulfill the requirements of the Biofuels Directive. Political efforts have led to a broadening of the deployment of crops, which can be used for biodiesel production. Since 01.01.2010, the same biofuel blending quotas as in Europe, as from 2011, a blending quota of 10% for biodiesel is required. Meanwhile, Argentina is among the top 5 bio diesel producers worldwide. In order to achieve this, nearly 1.3 million ha are planted with soybeans, but also sorghum and maize. Bioethanol is being produce mainly from the sugar industry from sugar cane molasses. However, Argentina counts among the 5 largest wheat exporters. In 2006, for example, nearly 2/3 of the total wheat harvest was exported (Nehring 2008).

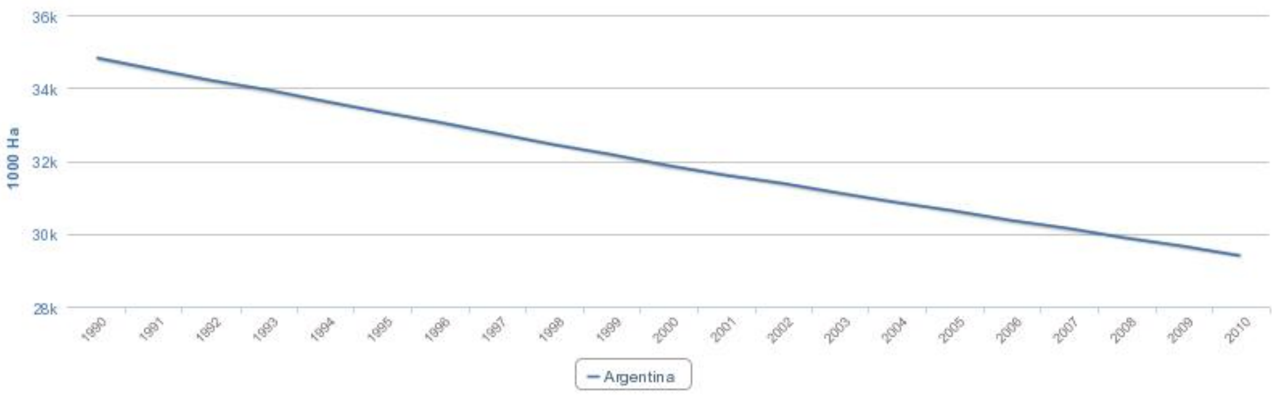

Figure 15: Forested area Argentina

Unlike agriculturally used land, Argentina's forested area has been diminishing since 1990. This trend has lead to a loss of forested area of nearly 1/5. Causes should mainly be seen in the widening of tilled land, but also in infrastructural measures and housing development.

The field of other Land has been strongly decreasing since 2002/3. Since here, as was described above, these include land use categories, which are definitely being returned to agricultural utilisation, the cause of this is mainly the intensification and widening of tilled land areas.

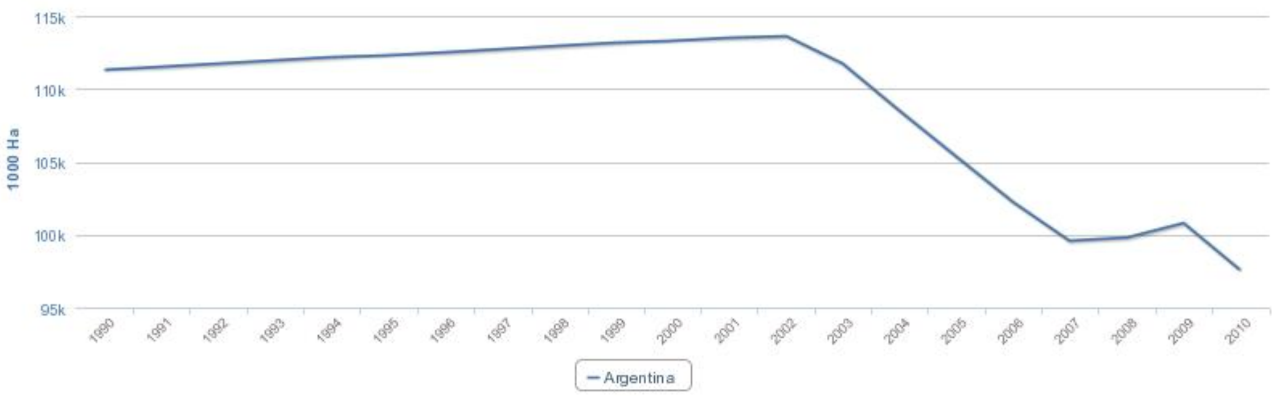

Figure 16: Other Land

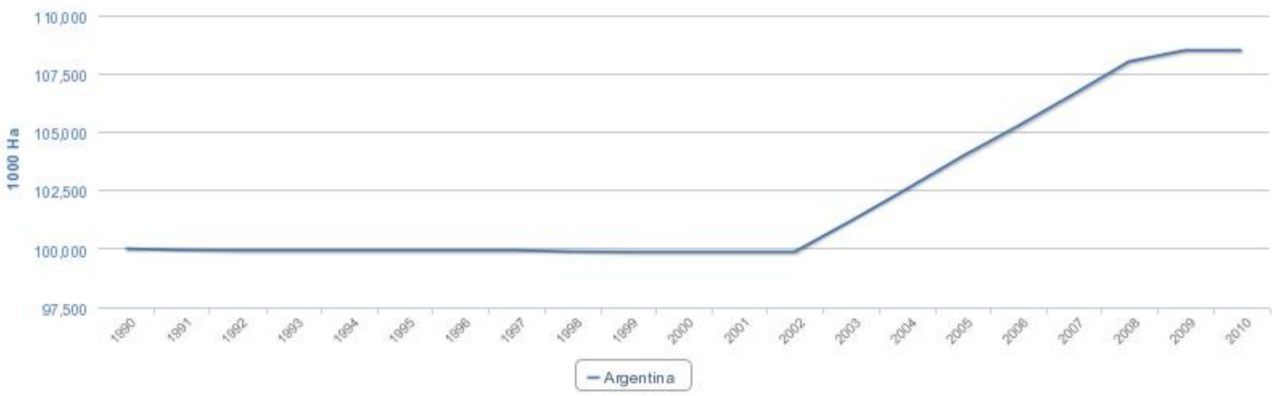

Figure 17: Permanent Meadows and pasture

As is also the case with the agriculturally used land, since 2002 the proportions of Argentina's grassland surfaces have been increasing. However, in considering grassland surfaces, the development of livestock, but principally of cattle, must be taken into account. From 2006 up until today, cattle herds diminished in size by nearly 15%. This has been mainly caused by a displacement of animal husbandry by tilled land. Furthermore, in 2008/2009, a severe drought struck the Pampa Humedo, the most important cattle region, and in its wake, an emergency cull of large numbers of animals had to be undertaken. Since 2006 commercial and food stuff restrictions of the government also contributed to a diminution of the production. Moreover, traditional Argentine cattle husbandry is changing from traditional pasture to intensive rearing, associated with intensive feeding. This is a result of the price limits for beef, which forced the producers to increase their meat yield per ha. But since beef consumption per head is also decreasing in Argentina, this evolution cannot be stopped. In 2012, Argentina only exported one quarter of the quantity it exported in 2004 (Araoz 2013). As a result of the drop in cattle farming, the proportion of permanent pasture in the regions, in which tilled land had not been lucrative enough, a mixture of extensification caused by the diminution in livestock and intensification of fattening in the end-phase can be observed.

In general, it can be stated that the expansion of soybeans and wheat crops for export displaced the classic Argentine cattle rearing on pastures. This activity is shifting to poor-quality soils, which leads to a reduction in animal numbers.

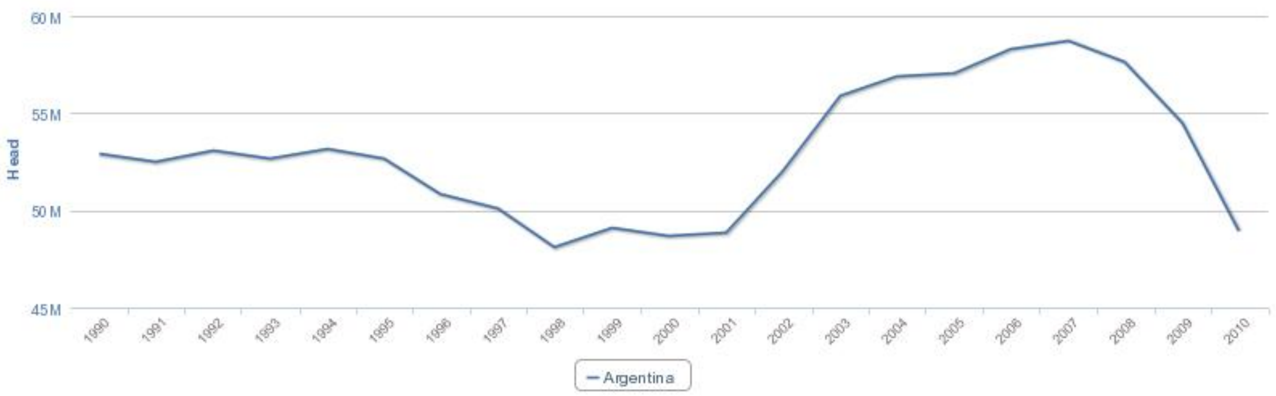

Figure 18 Live Stock Cattle

Argentina's export policy fluctuates considerably. Limitations are put on exports, which can go up bans on exports. Furthermore, export tax up to 30% on certain agricultural products have been levied in the past.

4.2 Australia

Australia, conversely, shows a picture diverging from that of the changes affecting Argentina. The loses of forest and agriculturally useful areas are now completely covered by the category „other Land". Especially in the case of agriculturally used surfaces, the reason for this can be the increase of dry periods, which preclude yearly cereal crops, so that no regular agriculture, but rather a rainfall dependent agriculture can take place. However, the extraction of raw materials is also displacing agriculture and forestry. The increase in population also causes an increase in other lands, because it includes infrastructure measures and sealing off for the development of dwelling and industrial areas.

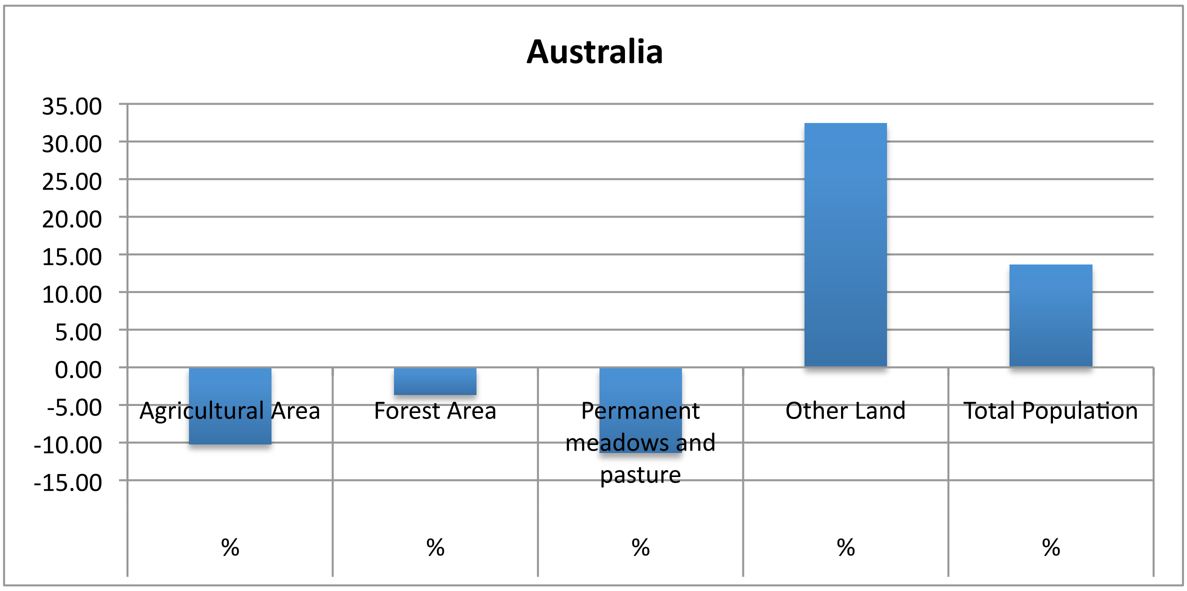

Figure 19 Land use change and population growth in Australia

As the following graph shows, Australia's agriculturally used area has been continuously diminishing since around 1998. Since 2006, this area has been distinctly decreasing. Australia's most important product from crop farming is wheat, which is produced on around 45% of agriculturally used area.

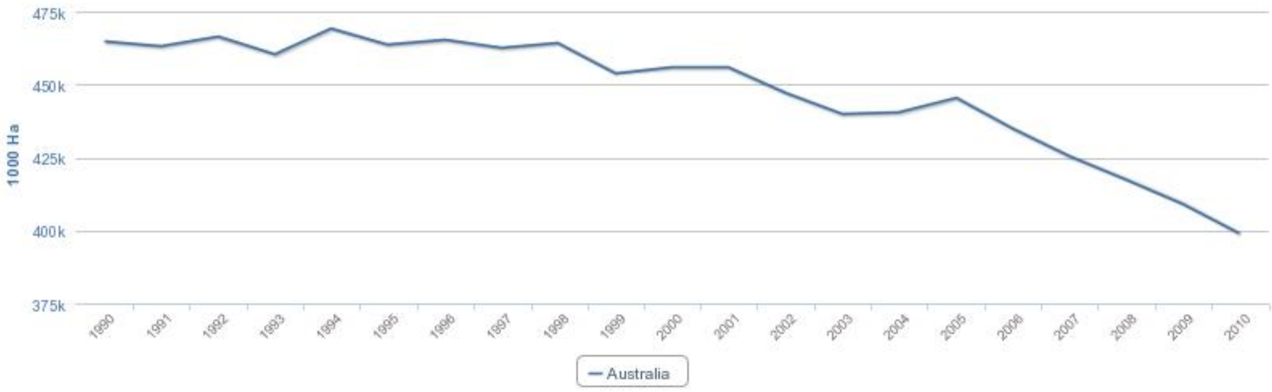

Figure 20: Agricultural Area

However, especially Australia is prone to extreme weather conditions, such as dry periods, but also flooding, as ha soften been the case in the past. A great proportion of the production stems from irrigated areas. Furthermore, Australia is one of the most important poppy-growing area fort he pharmaceutical industry.

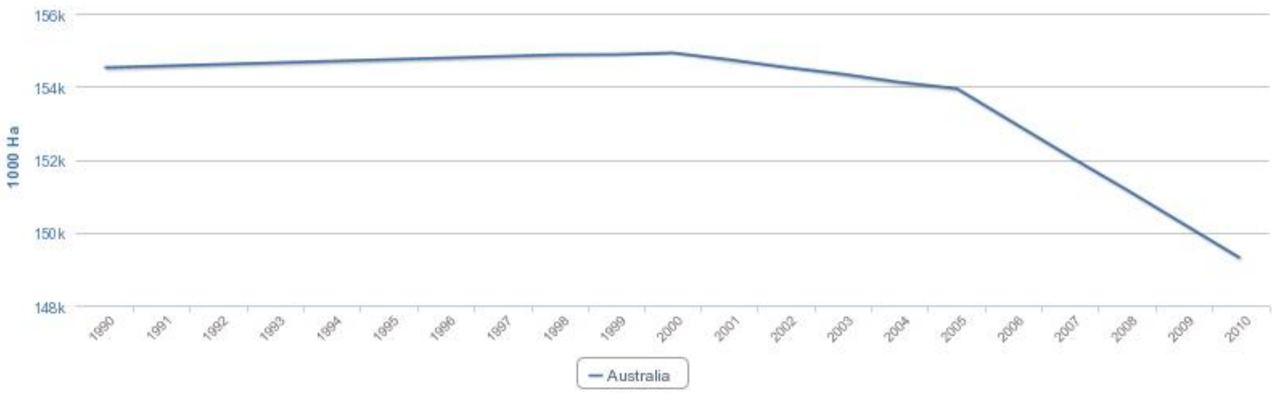

Figure 21: Forested Area

Fig 21 shows the changes of the category forested Area. The forest area has been strongly diminishing since 2005, after slight increases that took place up until 2000.

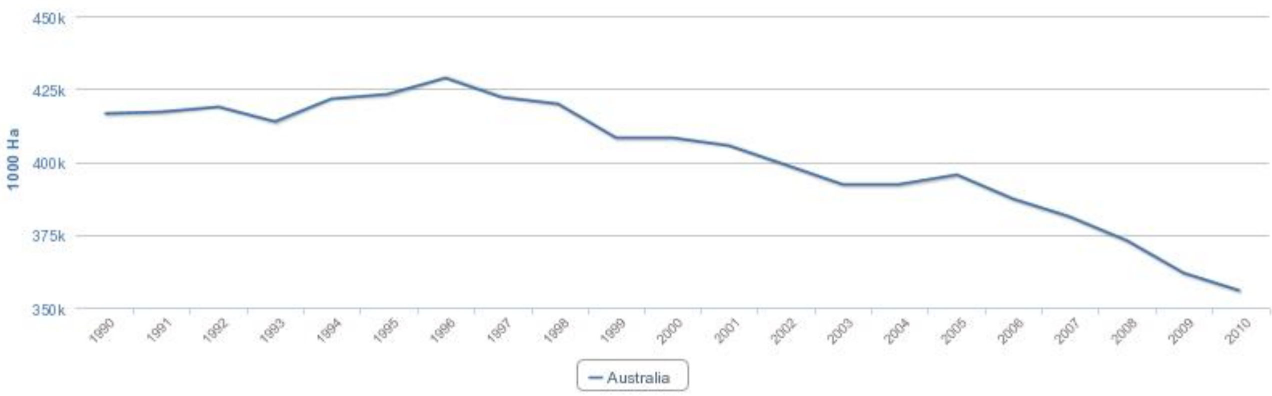

Figure 22: Permanent meadows and pasture

Likewise, grasslands are strongly affected by dramatic reductions. Grassland, however, remains an important economic factor for Australia, because, there, sheep farming is dominated the wool production.

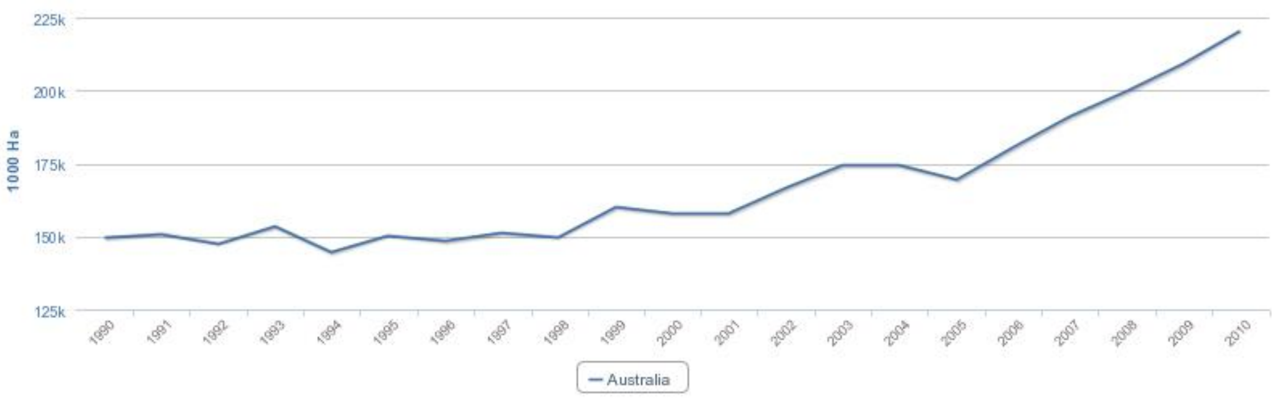

Figure 23 Other Land

On the other hand, the category „other Land“ also includes sealed areas, infrastructures and mining. Therefore, the question arises of how the actual surface utilisation stands in relation to the decline of forestry. This answer cannot be clearly derived from the analysed data sets. It is known that mining has been expanding at the cost of agriculturally used land. Principally in Southwest and southeast Australia, mining has since been encroaching upon vineyards.

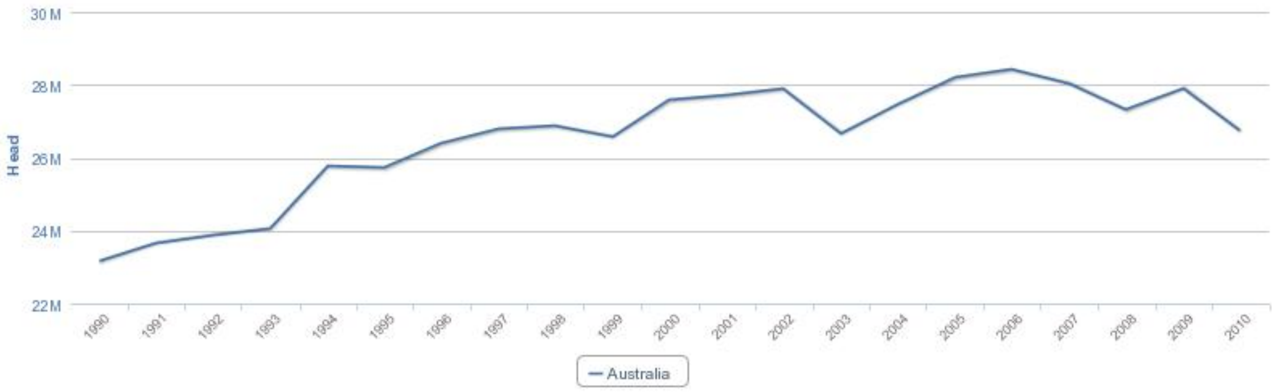

Figure 24: Cattle

Cattle farming have been cyclically increasing in Australia and have gone up by around 20% since 1990. Australia is an important beef and cattle exporter.

4.3 Brazil

In Brazil immense increases in the areas of the category „other Land“ have been reported. These represent, as a whole, the near integrity of the lost forest area of Brazil.

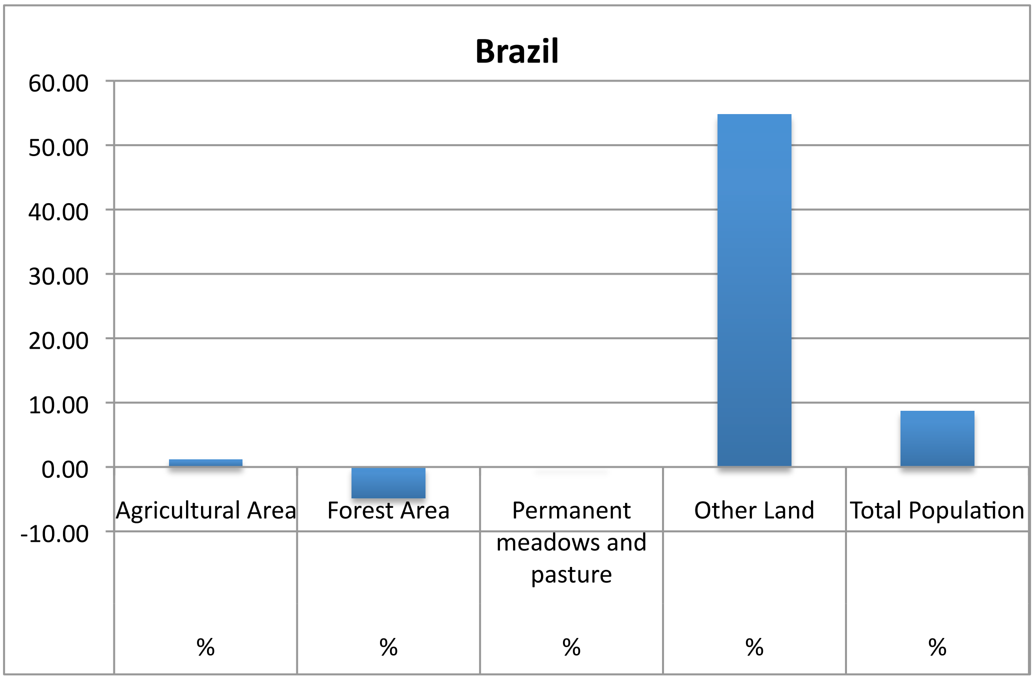

Figure 25 Land use change and population growth in Brazil

Brazil's Bioethanol Promotion Policy

Since the 1970ies, it has been possible to power Otto motors with ethanol. Since, at that time, the use of fossil fuels was cheaper, the further development of this technology has faltered. Only Brazil further expanded research and utilisation of bioethanol, in order to ensure energy security and to support its sugar cane industry, which had been stagnating.

After 2000, political and societal changes swept through many Latin- and Middle-American countries, whose explanation is to be found in their export-oriented resources policy. As a result, various (middle – to) left-wing governments were constituted which, however, were still dependent on the export success of their own raw materials (Schmalz 2009). After the change in government in Brazil in 2002, the government under Luiz Inàcio Lula da Silva also pursued moderate social democratic politic, which placed great emphasis on high exports in the agricultural sector (ibid). The demand for biofuels continued to grow thanks to the Agreement of Trade and Economic Cooperation between Brazil and the United States, signed in 2007. The end of this trend is difficult to predict, because the price of renewable energy sources depends on the evolution of the prices of fossil energy sources, which still account for around 90 percent of world-wide energy consumption (ibid).

The introduction of blending quotas in the USA and the EU carved an important space within Brazilian politics for the export of alternative energy sources and state promotion of bioethanol. The Agreement of Trade and Economic Cooperation between Brazil and the United States combined with an increased demand for bioethanol drove the export figures in 2006 to around 3.4 billion of liters. This means that Brazil exported 19 percent of its production, multiplying the 1996 export ratio by twenty. In the same period of time, the earnings of US-$m54 grew to US-$bn1.6 (Ansel 2009), making Brazil of the largest producer of bioethanol, with a worldwide share of 38 percent (Schmalz 2009).

The main explanation for this development is the Pró-Álcool Programme, launched in 1975. The reason for this promotional measure was the oil crisis of 1973/1974 and the falling world sugar prices. In the first oil crisis, the price of crude oil increased by around US-$9/bbl to over US-$12/bbl, while the prices for sugar on the world market dropped between 1974 and 1976 from US-$0.62/lb to US-$0.15/lb. Since the Brazilian sugar industry, which was guaranteed price stability thanks to high subventions, generated large over capacities, it was economical to produce ethanol from sugar cane. In the course of this price trend, ethanol and sugar producers demanded that the then military government promote alcool as alternative fuel. Thanks to this measure, ethanol production from sugar cane was to rise from 0.5bn l to over 3bn l (Giersdorf 2009).

The government adopted, moreover, blending quotas of 10 – 15 percent bioethanol in conventional petrol (gasoline) in the three most important sugar-producing federal states (ibid).

This was meant to assure the acceptance of the producers' sugar cane and ethanol and guarantee the use of biofuel in the traffic sector. In the course oft he 2nd oil crises in 1979, cars were developed, which were able to run on 100 percent ethanol, in order to counter the dependence on fossil energy sources. Furthermore, a countrywide blending quota of 20 was introduced in Brazil. Thanks to highly subventioned credits by the World Bank, further installations for the production of ethanol could be built, which lead to an increase in ethanol production to over 11bn l in 1985.

This has also boosted the sale of the alcool car, of which 500,000 pieces were annually sold since 1982 (ibid p 215-216). The automobile and sugar sectors were so massively subsidised that in 1984, 90 percent of all vehicles ran on such motors (Hetzer 2009).

In 2003, new vehicles were equipped with flex-fuel engines, which can run on any mixture of conventional fuels blended with ethanol (ibid). Compared to alcohol cars, these also offer the advantage of allowing the purchaser of the car to decide which proportion of alcohol and petrol they wish to fill, this making them more independent in their choice of fuel. Already in 2007, 90 percent of the cars sold in Brazil were equipped with flex fuel engines. A further incentive for the purchase of such cars was, furthermore, a reduction of the industrial production tax by 2 percent compared to conventional cars (Giersdorf 2009). Experts assume that the consumption of bioethanol will overtake petrol consumption in the next years and that the numbers of cars equipped with flex fuel motors will increase to over 50 percent (Köster, Funk 2009). Up until 2005, Brazil was world leader in bioethanol production, however, it was outpaced by the USA. Thus, in 2006, 14.06 MT bioethanol were produced in Brazil and 14.58 MT in the USA.

According to estimates, it is intended to raise the production to 34.76 MT in 2016, in order to further expand the important role of Brazil in the field of ethanol production.

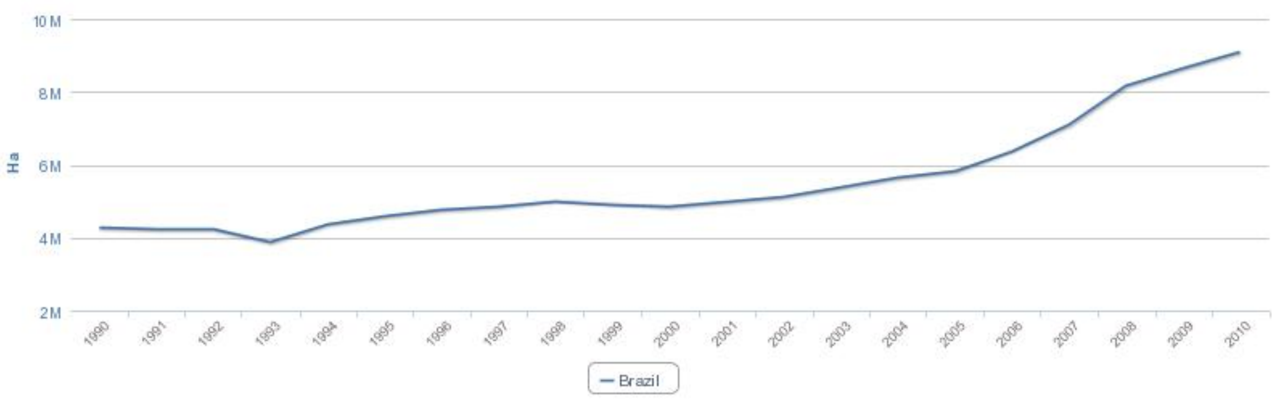

Figure 26: Brazil Sugar Cane

A further factor strengthening the dominance of Brazilian ethanol production, are the low production and land costs in Brazil, which are lying far below the European and American ones. While in 2003, a worker of the US State of Maryland earned at least US$14.13 a man-hour, the hourly wages in São Paulo were only between US$1.24 and US$2.65 an hour (Giersdorf 2009).

Furthermore, Brazil possesses a great potential for the production of bioethanol, because of its geographic diversity, as well as the availability of land surfaces. Thus, the State of São Paulo, where around 58 percent of Brazilian sugar cane is cultivated, provides the perfect conditions thanks to its geographic situation and climate for this plantation (ibid).

In spite of all its negative effects on humans and the environment, sugar cane cultivation offers a great economic potential. This, in 2006, over 17.7 million of cubic meters of bioethanol were produced from sugar cane, 80 percent of which were used in Brazil as fuel, thereby covering 40 percent of the total fuel consumption. 15 percent were exported, achieving high export performances. Thanks to this exports, US$1.6 bn in revenues were attained, in 2005, this figure was still at US$765.5m (Hermanns, 2007).

According to the Brazilian Federal Agriculture Ministry, the areas used to cultivate sugar cane are planned to be extended by 3 million ha until 2014 and sugar cane production, increased by around

50 percent. It is planned that production surfaces needed for this will be in Cerrado. Because of bio ethanol's increasing importance and the related land expansion, the prices for agriculturally used lands in the Sao Paulo region increased by around 113 percent between 2001 and 2006 (ibid).

Brazil's Biodiesel Subvention Policy

Brazil counts as the second worldwide soybean producer, covering around 25 percent of global soybeans needs (Suchanek 2010). The main part of the 250 MT of soybeans harvested in the whole world is used as fodder in intensive livestock farming, however the importance of soy oil for the fabrication of bio diesel, has been constantly increasing for years, which has lead to a further expansion of soya-cultivated areas (ibid). In 2005, the Brazilian government adopted a subvention programme for bio diesel, which provided for a statutory blending rate of 2 percent bio diesel for conventional diesel. This ratio is planned to be increased to 5 percent as from 2013, in order to lower the high duties on imported diesel (Giersdorf 2009). Furthermore, bio diesel has the advantage that it does emit less of sulfur components and limit dust pollution (Hetzer 2009).

It is planned that the cultivation of oleaginous plants for bio diesel production will offer support to small farmers in structurally weak regions. According to this scheme, enterprises of the bio diesel sector receive tax relief and a social label, when they buy their raw materials from small farmers. Thanks to binding contracts with large enterprises, the small farmers are guaranteed minimum purchasing volumes, fixed prices, as well as consultancy in agricultural matters for the oleaginous plants, castor-oil plants, soy beans and oil palms. In the light of the negative experiences endured because of the ethanol promotion programme, these measures aims at preserving small-farming structures and hinder the formation of an oligopolistic situation of a few large enterprises (Giersdorf 2009).

Even though Brazil possesses a high diversity of oleaginous plants, which are all suited to the fabrication of biodiesel, the soybean industry exerts an extreme domination. It has spread to a land surface of 21 million ha, corresponding to around 27 percent of the total arable land surface of Brazil. In the period of time between 2006 and 2007, around 58 MT soybeans were harvested. According to evaluation by the Brazilian bio diesel industry, in 2007, 80 percent of bio diesel was derived from soybean oil (Giersdorf 2009). In 2009, Brazilian agriculture exported over 28.5 MZ soybeans, leading to around US$11.4bn in revenues (FAOSTAT).

By fixing bio fuel blending quotas to 5 percent in 2013, the production is expected to increase to 2.4 bn litres of biodiesel, thus reducing Brazil's dependency on diesel imports. This saw the importation, in 2006, of around 3.5 bn litres of diesel at the price of US$1.7bn (Giersdorf 2009).

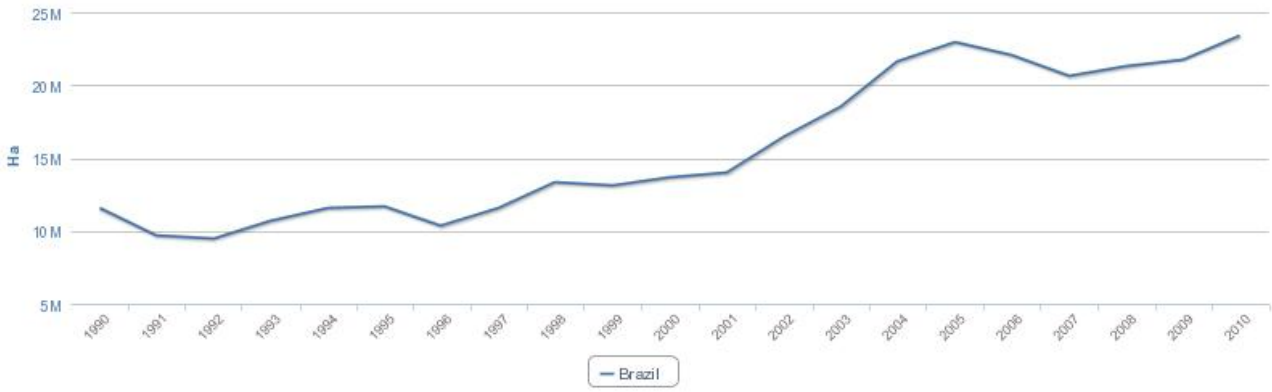

Figure 27: Brazil Soy Beans

In its national plan for agro-energy, the Brazilian Federal agriculture ministry established a land surface potential of 200 million ha of hand, which is suitable for the production of energy crops. This represents around 25 percent of the total of Brazil's surface (Hermanns 2007).

Brazil's future political development is also showing negative trends. The economic strategy based on cattle-breading and soybean cultivation has helped the agriculture lobby to deprive the once strong environmental agency of its power. This has lead to an amendment of the legislation concerned with forestry, providing an amnesty for illegal logging of primeval forest, which continues to accelerate the destruction of the rain forest. The modification of Brazilian laws on forest conservation recognises, furthermore, that the farmers of the Amazonas region have the right to clear 50 percent of their land, instead oft he 20 percent they were allowed in the past, which will in all certainly contribute to the deforestation trend.

4.4 Kazakhstan

Kazakhstan, spanning over 2.7 million square metres, represents a very large land mass and has only around 16 million inhabitants (2009). Great regions in Central Kazakhstan are in part not at all or only scarcely populated (UN OCHA 2009). Urban and rural population has slightly grown within the period studied. The population, which is active in agriculture, on the other hand, sank to 2.526 million inhabitants from 2000 to 2009, the proportion of agriculturally active population to the total population, was only of around 15%.

In 2009 Kazakhstan had, with its 2.085 million square meters, the largest agricultural land of the research, of which nearly 89% were constituted by permanent pasture and grazing land. Permanent crops were hardly planted. The increase of agricultural land from 0.017 million square meters was totally imputable tot he increase in tilled land within the period studied. The area for wheat increased in parallel significantly and can, therefore, be classified as the primary cause oft he increase in arable land. Next to the expansion of wheat crops, sunflowers and rapeseed represent a not insignificant share oft he increase in arable land. Unlike Indonesia, the increase in tilled land happened nearly exclusively at the cost of residual areas.

Kazakhstan is situated in Central Asia between around 46° to 87° east longitude and 40 ° to 55° north latitude and is land-locked. Because of Kazakhstan's inner continental location, it is subject to an extreme continental climate, characterised by hot summers and cold winters, as well as low rainfalls (Pauw 2007).

In Kazakhstan, four different types of land cover depending on the natural site factors are standing out: wooded steppe, steppe, semi-desert and desert. Wooded steppe covers around 4.4% of the land surface and is located mainly in North Kazakhstan. It consists of a spread-out steppe interspersed with forest areas. With increasingly dry climate, a steppe zone is replacing wooded steppe as one moves south, representing a predominantly shallow prairie. The prairie covers around 20% of Kazakhstan. The semi-desert is the transition zone between steppe and desert and extends from east to west into the interior of the country. In total, it covers around 17% of Kazakhstan. Expanding on around 44% of Kazakhstan, the desert zone represents the largest land cover, spreading over vast areas of lowland and extending to the south from east to west (Grote 1997).

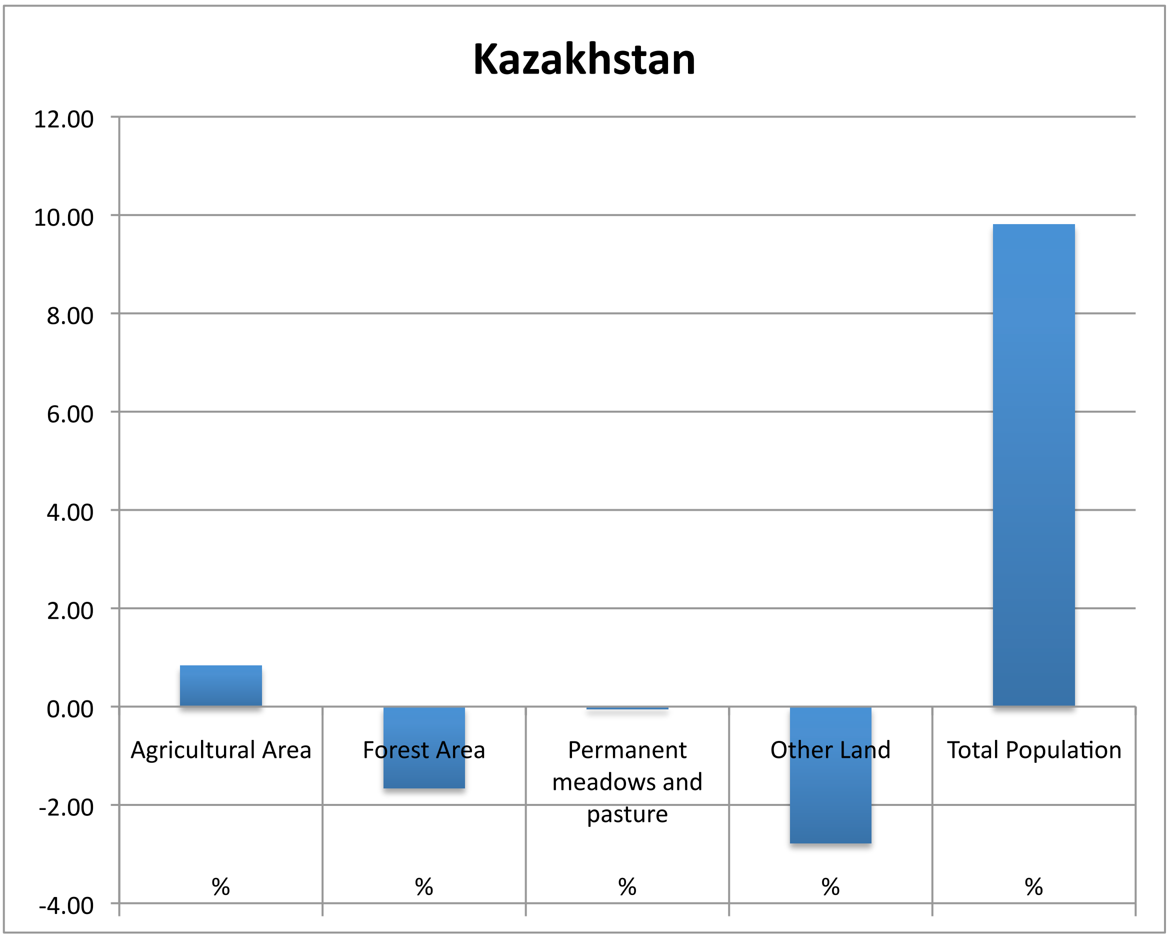

Figure 28: Land use change and population growth in Kazakhstan

Without more detailed information concerning the utilisation of the land covers, the deserts and semi-desertic zones would be classed to the residual areas. The steppe zones can be broadly classified as permanent and non-permanent pastures, because it fulfills the criteria for wild grown prairie. Conversely, wooded steppe could fall into the category of forest area or another wooded area. In order to do so, more information concerning vegetation cover and utilisation is however needed. Hence, deserts and semi-deserts, which represent scarcely vegetated or sandy land cover could provide the explanation for the decline in residual areas.

Agriculture in North and Central Kazakhstan is charaterised by extensive cultivation of cereal crops and animal husbandry. The steppe is mainly used for wheat and forage plants, as well as for cattle and sheep farming. In South Kazakhstan scarce agriculture appears, which features extensive cultivation and animal husbandry, which, however is strongly limited by water scarcity. Nomads only use the most arid regions. In Southeast Kazakhstan, aridity is forcing agriculture to return to some forms of pastoralism. Furthermore, in scattered regions of South and Central Kazakhstan irrigated agriculture is carried out mainly for cotton and rice (Dixon et al. 2001).

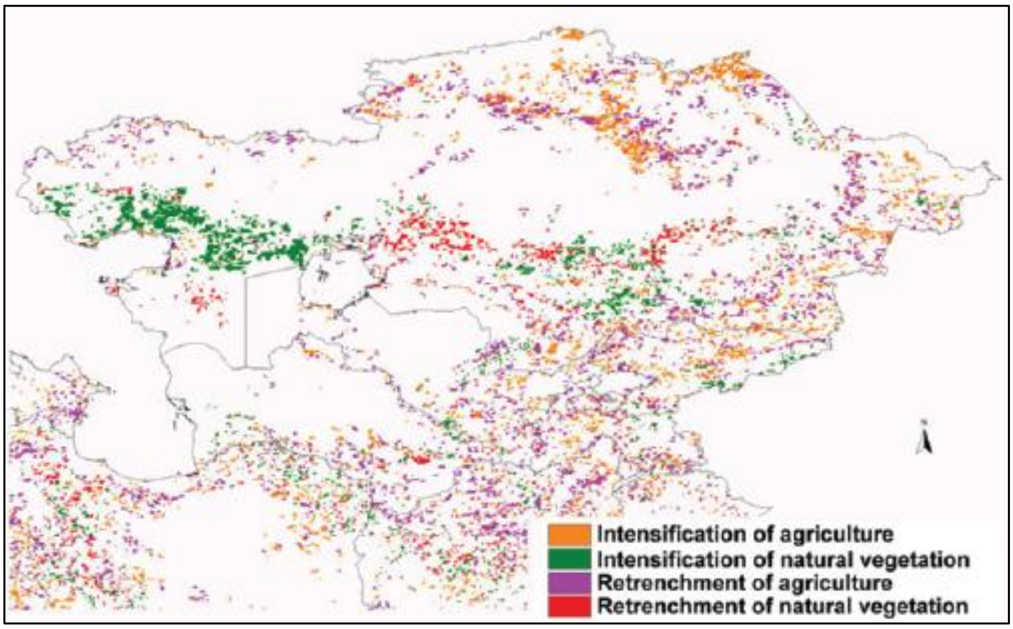

Figure 29: Spatial distribution of land cover changes in Central Asia. Source: Celis and de Pauw (2009)

The analysis of Celis and Pauw (2009) show a clear intensification of agriculture in Central Asia, which is primarily noticeable in North and South West Kazakhstan. In the North, the intensification occurred mainly as a result of the conversion from herbage and open scrubland to rain-fed annual crops. Conversely, in the South West, natural surfaces featuring bare / sparse vegetation to grass areas and scrubland, this conversion has been intensified. The expression used „Intensification of agriculture“ by Celis and Pauw means the change from a less intensive form of agriculture to a more intensive one and refers to the intensity of biomass production of the agricultural form. The intensification of natural vegetation means, on the other hand, the change from a less intensive climax vegetation 6, the relatively stable state of a vegetation in succession.

Consequently, the land cover changes identified by Celis and Pauw can either be interpreted as modifications of agriculture, as, according to this analysis, the changes remain within the classification of agricultural land: for example, the changes from grassland to rain-fed annual crops point to a modification from pasture land to wheat crops. Or the less intensively used land cover, in the example of grass surfaces or scrub land, point to ancient fallow land, which has been returned to agricultural use.

Furthermore, this can lead to the supposition that the intensification of agriculture and of natural vegetation represent a transformation. These surfaces are deteriorated and are situated in a destroyed (eroded), modified initial stage (scarcely vegetated) or in extreme case, even devoid of all vegetation. In the course of time, a transitional vegetation (for example Grassland) establishes itself until, a vegetation climax (for example open scrubland) on this surface has replaced it. This transformation would explain the taking-over of residual areas by tilled land. Surfaces covered by transitional vegetation, such as sparsely vegetated areas, which had been used in the past, in order to replace natural surfaces with climax vegetation, such as other wooded areas (in the form of open scrubland), were replaced mainly by rain-fed annual crops.

The change of the other wooded areas into wheat crops has also been documented by Beurs et al. (2004). The Nordic wooded steppe, which was classified as scrubland by Celis and Pauw, has been converted to 13% wheat crops, of which 37% are dry tilled land with wheat crops and 51% mosaic landscape alternating tilled land and forest area. The Northern non-wooded steppe zone was converted at the rate of 21%, of which 48% are utilised as tilled land and 27% is characterised by a mosaic landscape alternating tilled land and forest area. Mosaic landscapes alternating tilled land and forest area, however, point to agro-forestry and is not counted among agricultural surfaces.

Conversely, recent studies by Sommer and Pauw (2011) and Kamp et al. (2011) uphold the decrease of residual areas resulting from the supposed transformation of modified native land covers. Sommer and Pauw’s (2011) findings, which relate to Celis and Pauw’s land cover changes, see the conversion from natural barren land to rain-fed and irrigated agriculture in Central Asia, as well as the deterioration of Kazakhstan’s pastures as the main reason for the release of carbon dioxide. Kamp et al. (2011), on the other hand, see, in the renaturation of ancient tilled land from Soviet times as having a positive effect on the bird population, which, however is being influenced by the current trend to reclaim ancient agricultural surfaces. Not only Sommer and Pauw’s findings, but also those of Kamp et al., may, as a consequence, be perceived, in the same way as those of Celis and Pauw, as a evidence of the diminution of sparsely vegetated areas (in form of barren land) and fallow land.

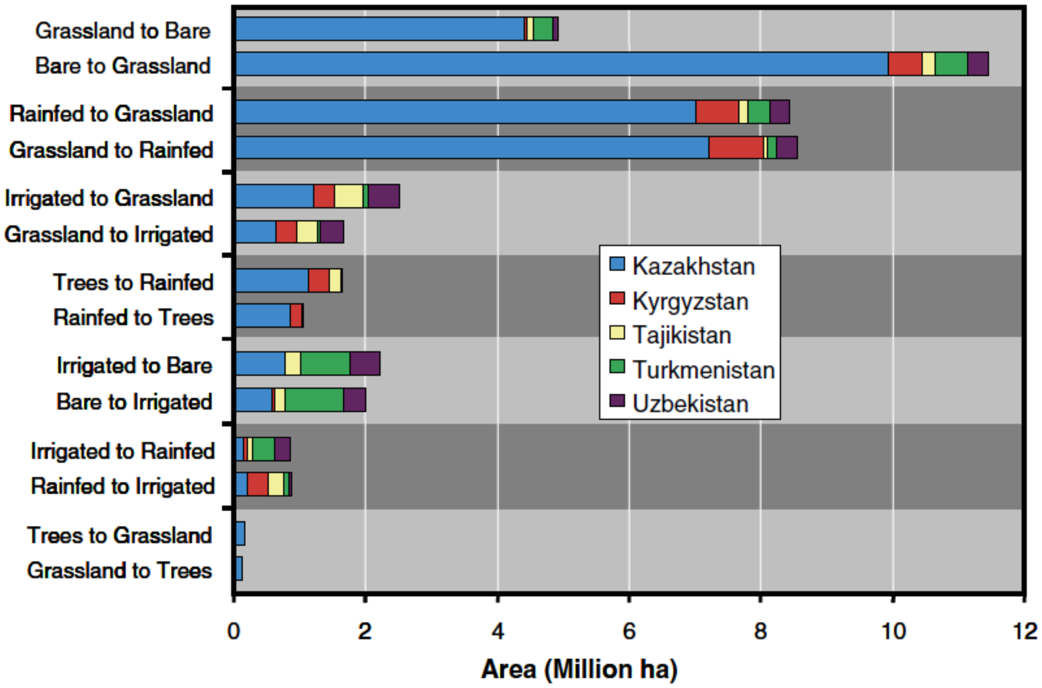

Figure 30: Changes in land cover and land-use in Central Asia from 1982 to 2000; bare lands (degraded land, deserts). Source: Sommer and Pauw (2011)

In Kazakhstan, land-cover changes are mainly characterised by the diminution of von sparsely vegetated surfaces and other wooded areas in favour of tilled land. This can be explained as follows:

The collapse of the Soviet Union and Kazakhstan's related attainment of independence in 1991, led to the abandonment of around 26 Mha agricultural lands (Lambin, Meyfroidt 2011). The USSR had, before then, transformed Kazakhstan from an originally nomadic to an agrarian society. As the command economy was being founded, the region of today's Kazakhstan was assigned to wheat production, a task, which was implemented to a large extent. With the institutional change of the agricultural sector, which resulted from the collapse of the Soviet Union, huge losses in wheat production (-33%), and livestock (-70%) ensued (Chullun, Ojima 2002; Alaolmolki 2001). This major political change leads to food shortages and a diminution in the production of export products, especially wheat. The abandoned surfaces described were „reclaimed" by nature in the course of time and grew to wooded areas.

The reason behind the reclaiming of agriculturally used lands is presumed to be demographic change and the increased need for foodstuffs. However, what is referred to as the „land reform" should be mainly designated as the main cause. Under that reform, proprietary rights in the form of temporary, as well as long-term land-use rights for agricultural surfaces can be acquired by private persons. This land reform aims at introducing an efficient system, which will contribute to agricultural production growth, and the improvement in welfare of the rural population in the regions concerned. In this scheme, wheat represents the main crop. It is extensively cultivated in large regions of Kazakhstan. The reason for this can be found, on the one hand, in the favourable climatic conditions for this type of cereal; on the other hand, a self-sufficiency system developed in Kazakhstan after it acquired its independence, which led to a strong wheat production.

Wheat represents a cost-efficient source of food for Kazakhstan's poor, rural population, which represents around 90% of the total population. This positive development has been encouraged, principally by the „oil boom“, which enabled Kazakhstan to establish a broad infrastructural provision for rural regions. Furthermore, the government of the country was now in a position to grant tax relief for the establishment of large, profitable agricultural plants, in particular in the North oft he country (Almaganbetov 2005; Kuo et al. 2006, 108-109).

4.5 India

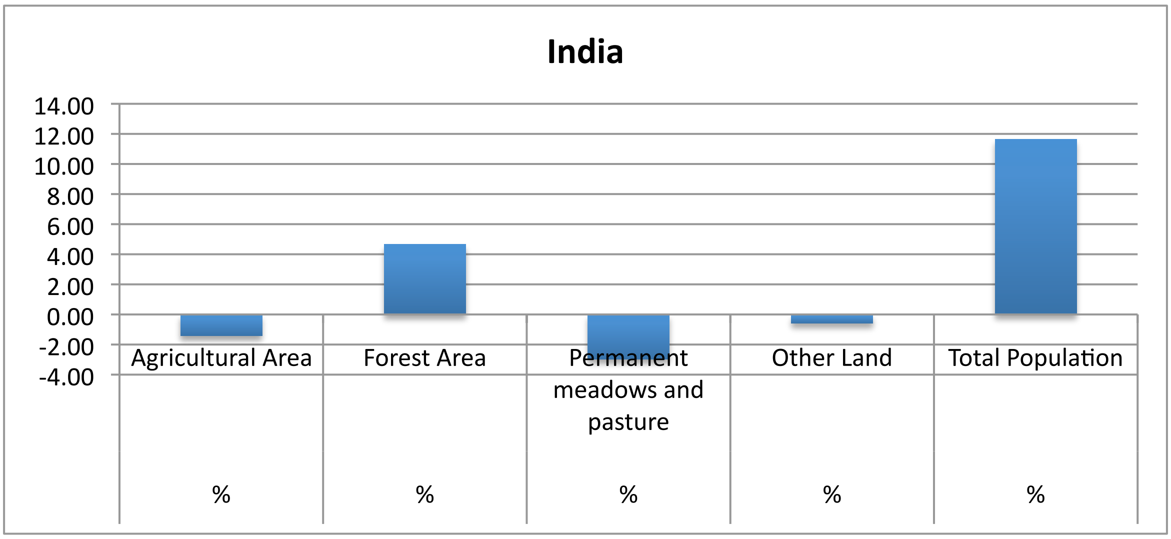

Figure 31: Land use change and population growth in India

Compared tot he other states investigated, land-use changes in India are conspicuous neither in percentage, nor in absolute terms. The decrease in agriculturally used land and the surface „other Lands“ reflect approximately the increase forest area.

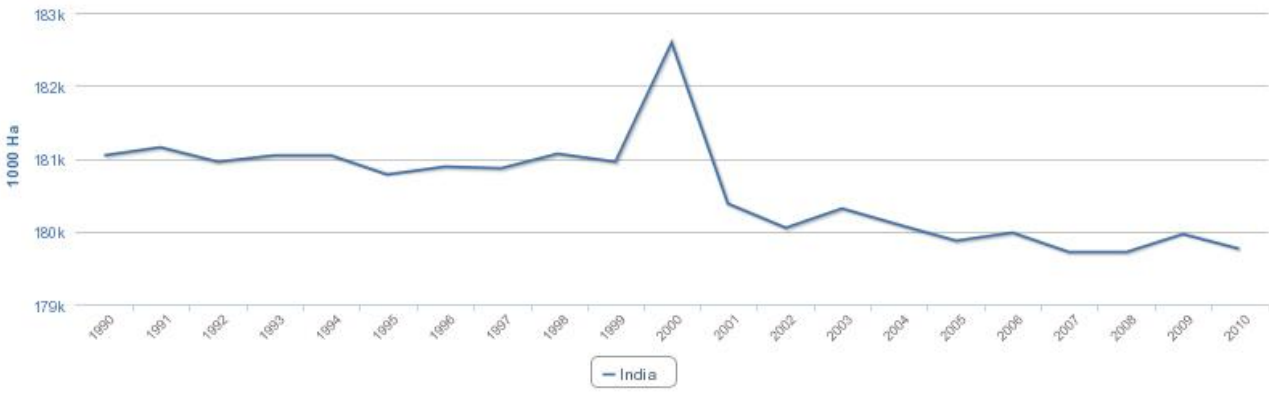

Figure 32: India Agricultural area

India has started a reforestation programme, whereby the forest area slowly increased and agriculturally used area decreases a little. Since a diminution has also be registered in the category other Land (Fig. 35), not only agriculturally used land, but also surfaces not directly falling into this category are reforested.

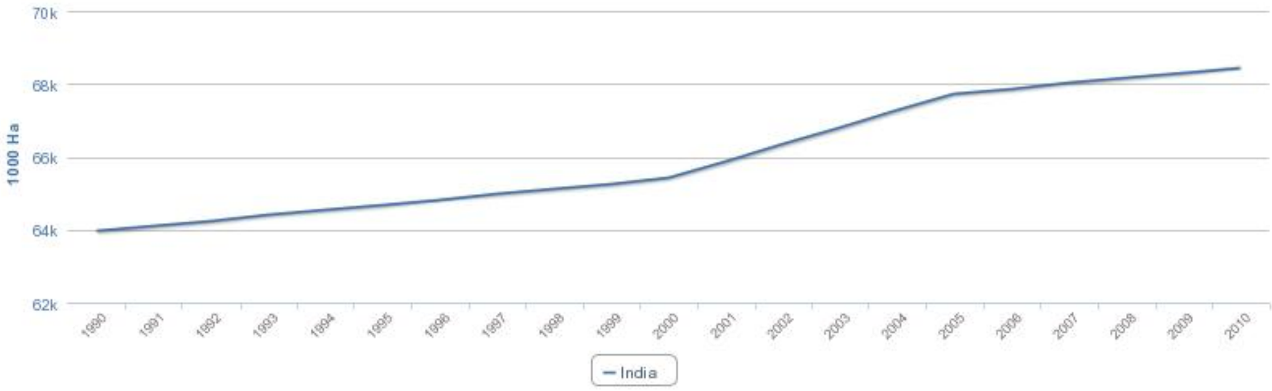

Figure 33: India Forested Area

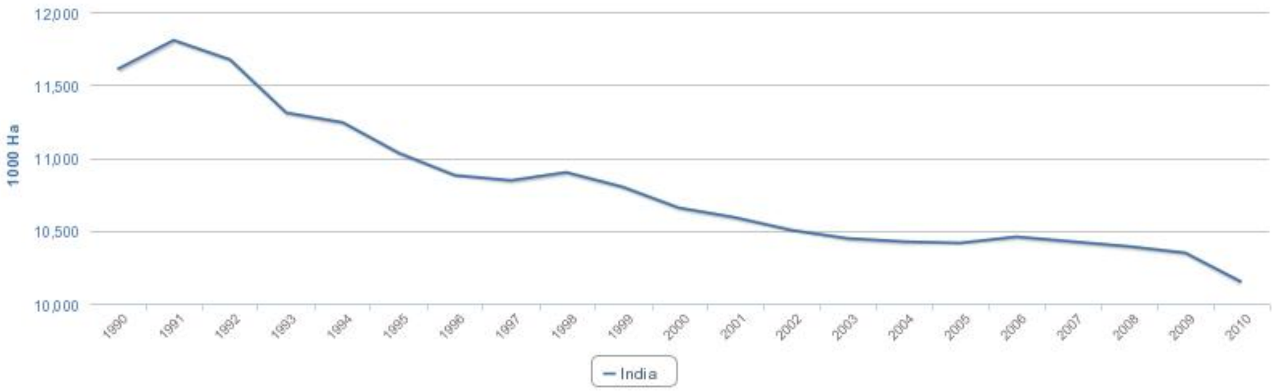

Figure 34: India Permanent Meadows and Pastures

The slight diminution of the category Permanent pasture cannot be explained from existing data.

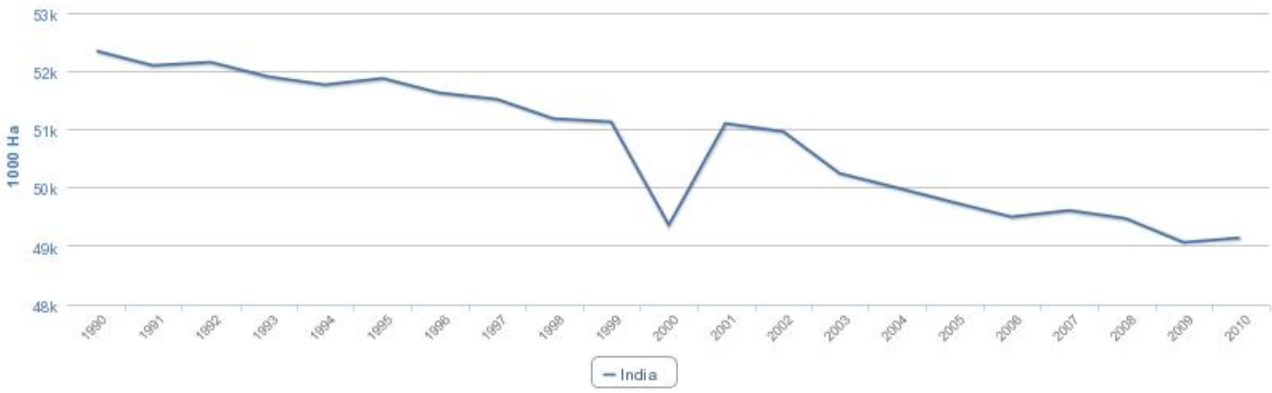

Figure 35: India Other Land

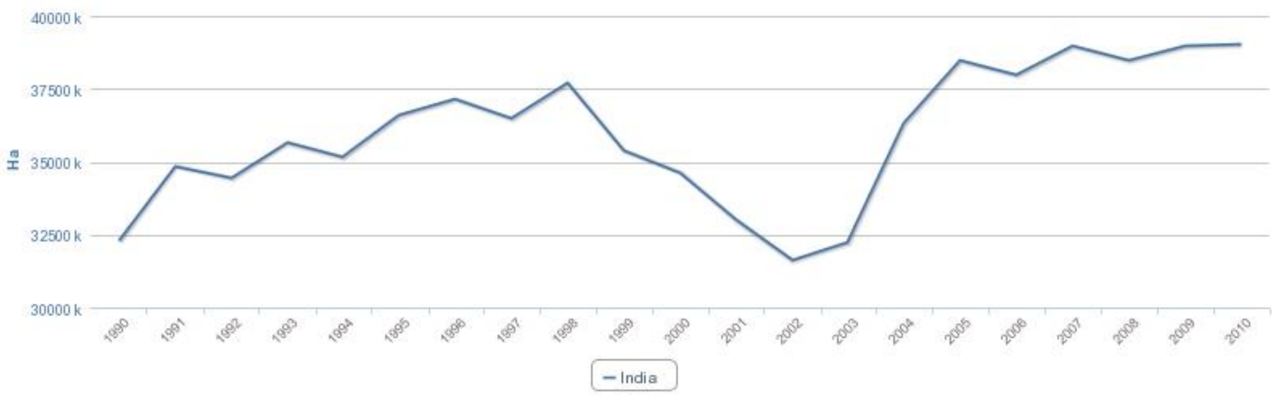

Figure 36: India Oil crops

In the course of the past 10 years, India initiated some oleaginous crops projects, such as jatropha. These might be reflected in the figures.

Population growth in India is extreme and becoming furthermore urbanised. Moreover, the average income of recent years has increased, even if this has hardly pervaded rural population, whereas the metropolises have seen the development of a better-off middle class. The diet changes involving more protein that this brought about are reflected mainly in fowl production and the increase of intensive poultry farming. Fig 34 illustrates this state of affairs very clearly.

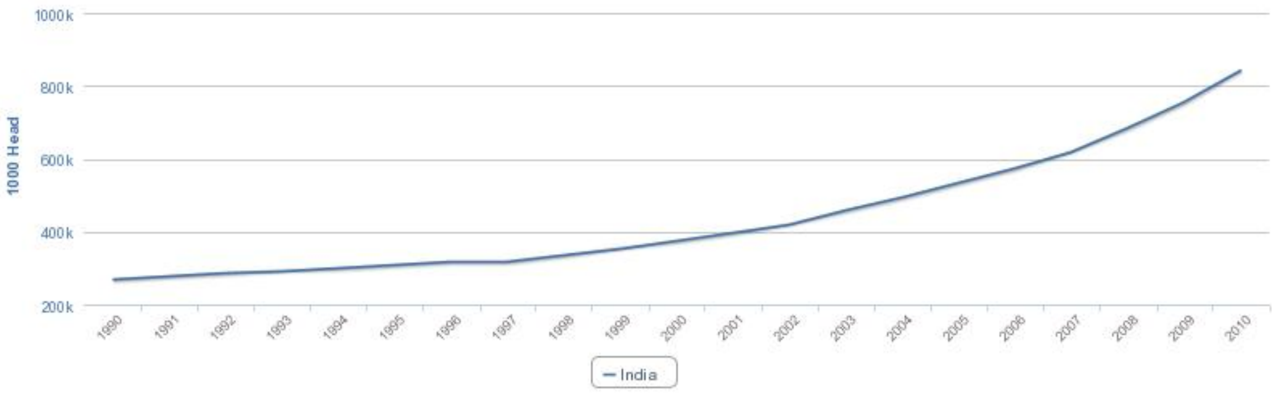

Figure 37: India Chicken population

4.6 Indonesia

Indonesia has, with its around 1,8 Million square meters, a small land surface, but with its around 237 million inhabitants (2009), a large population. The population density's average was near 131 inhabitants per km2. Some regions of Java and Sumatra Islands even show population densities between 501 and 2500 inhabitants per km^2 (UN OCHA 2005). The clear increase in urban population and decrease in rural population from 2000 to 2009 clearly illustrate the seriosity of rural exodus and the trend to urbanisation, which also negatively impacts the population active in agriculture.

Indonesia's land cover consisted, in 2009 of around 52 % forest area, nearly 30 % in agricultural surfaces and around 18 % in residual areas. This means that Indonesia, with its 0.951 Mhm^2, possesses a very large forest area.

From 2000 to 2009 the surface covered by agricultural land in Indonesia grew by 0.079 million square metres. The forest areas, which diminished by 043 million square metres, were the most affected by this increase. But the decrease in residual areas is also not insignificant. A closer look at agricultural surfaces reveals that the increase in tilled land and permanent crops is cause by permanent cultures. The observation of all agricultural crops listed by FAOSTAT found that the harvested areas planted with coconuts, maize, palm oil fruit and paddy rice grew the most within the same period of time. Thus, the increase of arable land can be explained by the increased space requirements of maize and paddy rice and the associated surface made for permanent crops, as well as by the rise in demand of palm oil fruits and coconuts.

Indonesia is the largest archipelago state on Earth, with 13,677 islands in total. The largest islands are Sumatra, Kalimantan (Borneo), Java, Suwalasi and New Guinea. The state territory extends in space between the around 94° to 141° east longitude and 6° zp 11° south latitude, so that the islands straddle the equator. The climate is mainly humid tropical with regular rainfalls and low annual temperature amplitudes. The yearly precipitations in the North of Sumatra attain approximately 1.600mm and on Borneo around 2.700mm (Stibig et al. 2007).

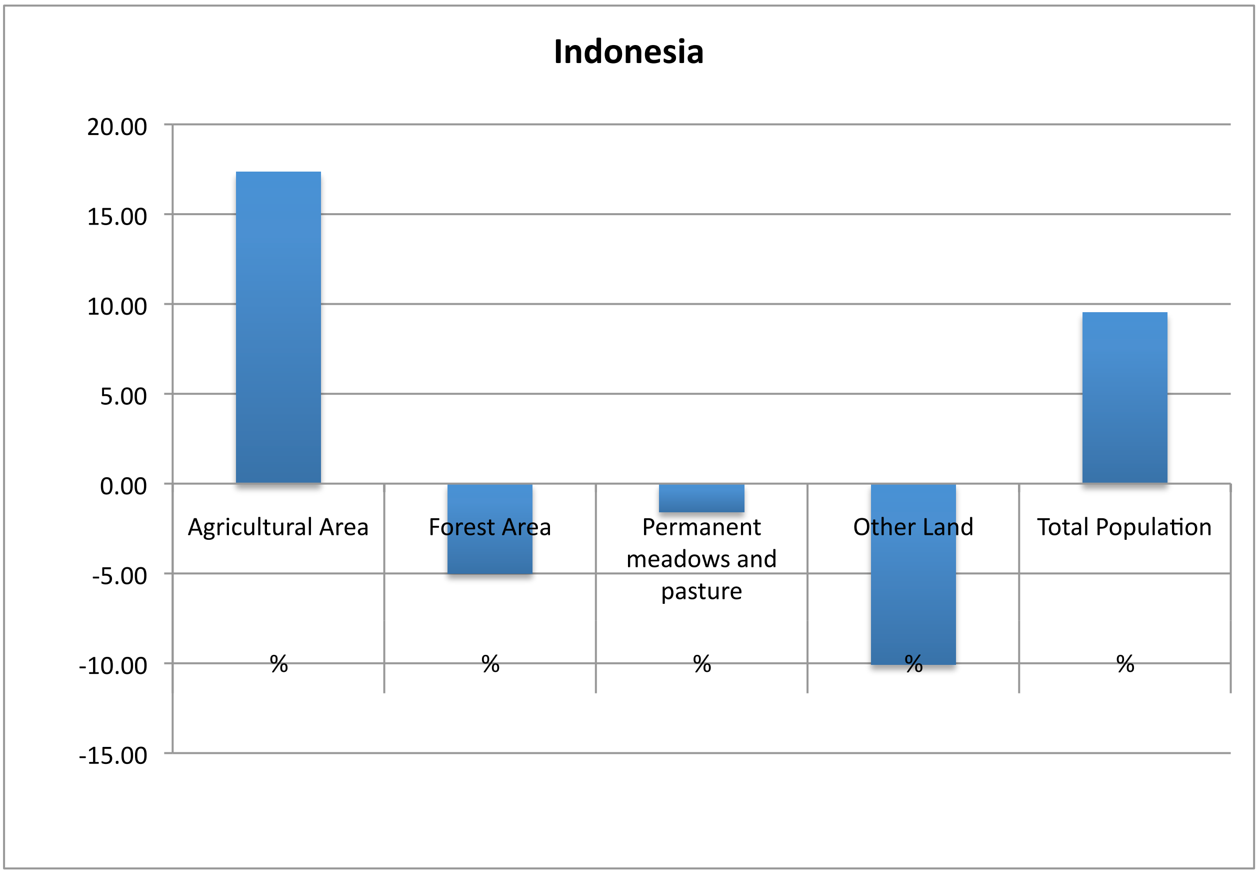

Figure 38: Land use change and population growth in Indonesia

Indonesia’s most dominant land cover is forest area, of which the humid-tropical rain forests and low- and highlands constitute the greatest part, followed by mangroves- and moorland forests. Mosaics of evergreen tree structures and natural vegetation, evergreen shrubs and what is referred to as regrowth as well as grasslands and Agricultural land, which are constituted partly of perennials and natural vegetation or cultivated and irrigated, were identified as further land cover for the insular South East Asia (Stibig et al. 2007). These land-cover classifications have been taken over for Indonesia and are considered as orientation point for further analysis.

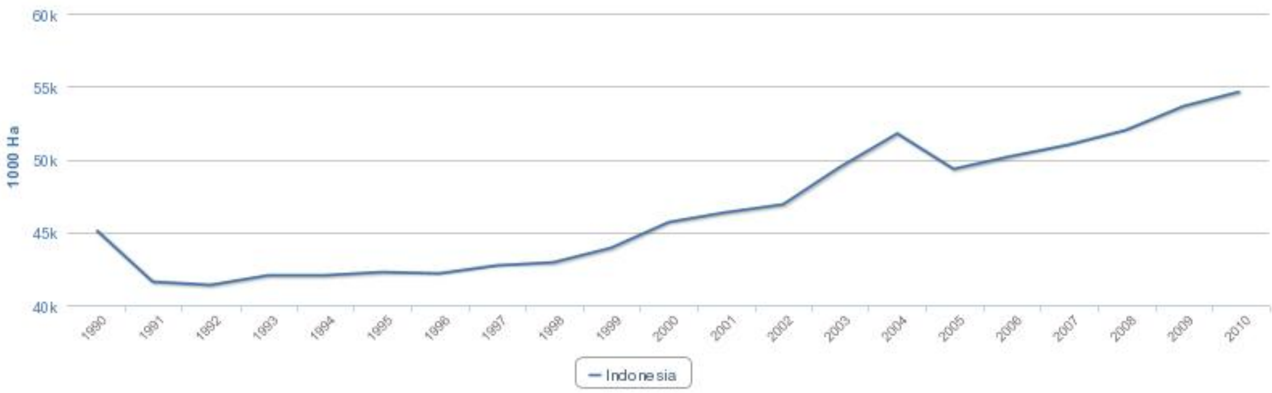

Figure 39: Indonesia Agricultural Area

Because of the dominance of tree vegetation in Indonesia's land cover the areas, which feature trees, but which do not fulfill the criteria of classification as forest areas, are above all interesting. These could be other forested areas or mosaic-type of agricultural surfaces. Above all, mixed agricultural systems for timber trees, natural rubber, palm-oil fruits, coconuts, tea, cocoa and coffee beans mainly are found in agro-ecologic zones and occupy great areas in Kalimantan (Borneo) and Sumatra. Timber trees are used not only on large private holdings, but also in small farms and are the traditional source of export revenue (Dixon et al. 2001).

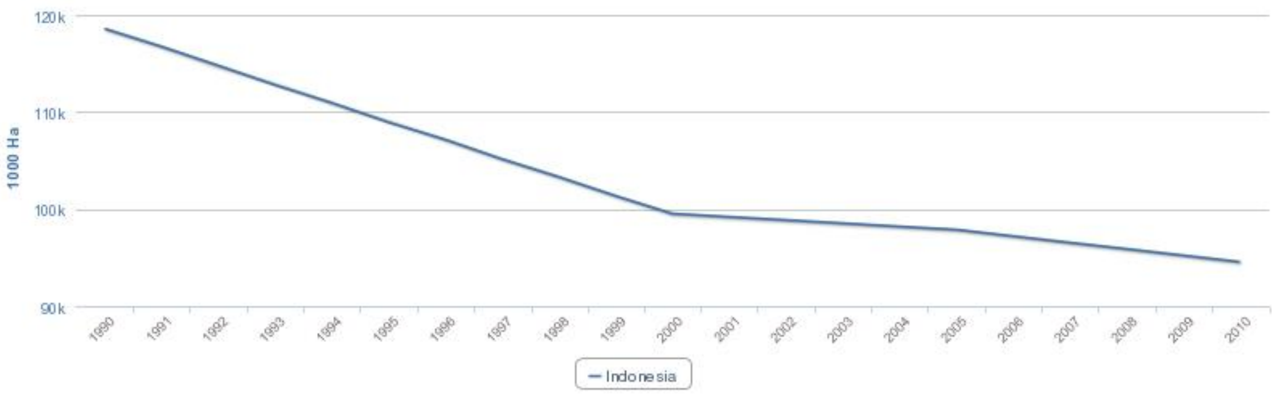

Figure 40: Indonesia Forested Area

Intensive rice cultivation is found on all five main islands, where the lowlands of Java have the most productive rice cultures. According to evaluations, rice paddies constitute around 37% of agricultural land and 90% of them are irrigated or dependent on rain. Since paddy rice is cultivated on water-covered soils, water management takes on major importance (Maclean et al. 2002).

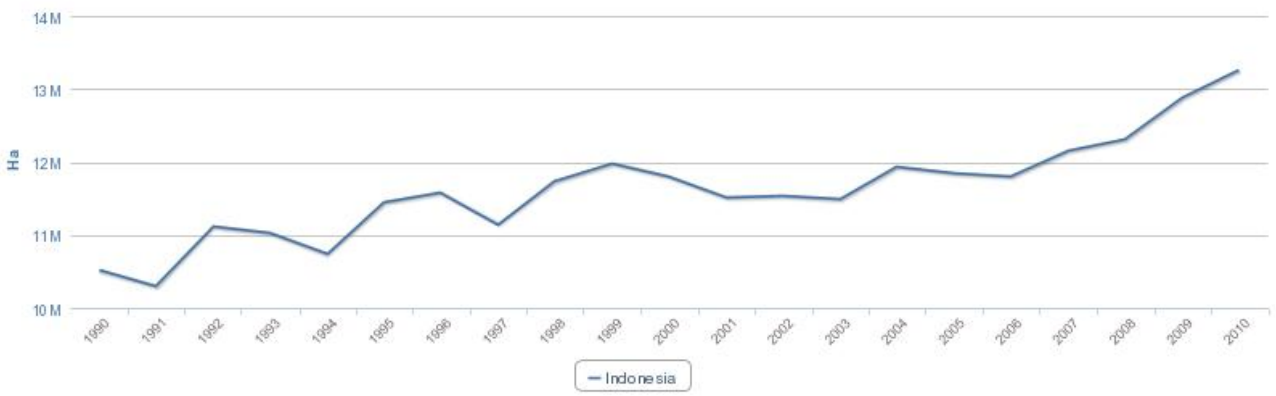

Figure 41: Rice Indonesia

Indonesia's highlands feature intensive, mixed agricultural systems, characterised by a spectrum of long-term crops, rice or animal husbandry, according to geographic and agro-climatic conditions. Furthermore, the combined sizes of the areas used for tiny, scattered agricultural settlements in Kalimantan's and New Guinea's tropical rainforest should not be underestimated (Dixon et al. 2001, 224).

The work of Schmidt-Vogt et al. (2009) provides an overview of a total of 67 articles, which describe the various change and conversion patterns in shifting cultivation in South East Asia. For Indonesia, 12 articles show how shifting cultivation has been supplanted by the cultivation of palm oil, natural rubber, fruit trees and rice. 7 articles document the reduction of fallow duration within shifting cultivation, and one article points to the deforestation effect of shifting cultivation. The disappearance of shifting cultivation systems is also evidence of the diminution of residual areas, because, according to FAO classfication, shifting cultivation systems are not excluded from agriculture. FAO's definition only excludes abandoned tilled lands are resulting from shifting cultivation from the classification. However, shifting cultivation systems often do not appear on maps or in statistics (Padoch et al. 2007). While deforested or harvested fields in shifting cultivation can be identified as agricultural lands, the surfaces, which are no longer used after having been in shifting cultivation, are often not recorded. The difficulty of identification resides in the fact that shifting-cultivation systems are closely linked with transitional vegetations, which changes from year to year (Schmidt-Vogt et al. 2009). The land cover, which is linked to the shifting cultivation phase, can be classed in the „abandoned surfaces" of residual areas classification (Fox 2000). The conversion of shifting cultivation to the above-named agricultural surfaces can, therefore, be considered to be an indication that, as a consequence, residual areas always result from shifting cultivation. These are eliminated, however, in the course of the conversion.

A clearer indication for the nature of the residual areas, which are disappearing because of agricultural surfaces, is found in a study by Carlson et al. (2012), which evaluated land cover changes resulting from the spread of palm oil plantations in Kalimantan. From 1987 to 2008, next to forest areas, secondary forests, deforested and agro-forestry surfaces, agricultural fallow lands, burned, felled surfaces and barren surfaces have made place for palm oil plantations. The findings of Carlson et al. confirm those of Schmidt-Vogt et al. insofar as these indicate that other agricultural and forest areas are diminishing. While the results of Schmidt-Vogt et al. point to a conversion of abandoned surfaces to agricultural surfaces (in the form of palm-oil plantations), Carlson et al. speaks of a diminution of mosaic type surfaces (in the form of agro-forestry) and fallow lands in favour of palm oil plantations. All three types of residual areas fall under the classification of other agricultural and forest areas.

Wicke et al. (2011), Feintrenie et al. (2010 and 2009) and Parikesit et al. (2005) all come to similar conclusions on the decrease of mosaic type agriculture (in the agro-forestry form) and expanding cash crop plantations. Feintrenie et al (2010) describe with their interviews that some local farmers in Sumatra and Sulawasi are increasingly deciding on monoculture plantations with perennial cash crops, instead of mixed agricultural tree systems. They describe the conversion from slash-and-burn agriculture to agro-forestry and finally monoculture plantations as typical trajectory. Also the study by Parikesit et al. (2005) makes clear that the fields dedicated to agro-forestry systems in Java are yielding to more productive agricultural surfaces, such as cash crop fields.

Wicke et al. (2011) on the other hand, have determined that his „other land“ classification for Indonesia has been diminishing since 1999 and are speculating that fallow land (in the form of deforested, forest areas left fallow) is used for agricultural sprawl. Nearly half of agricultural sprawl is attributed to the spread of palm oil plantations, which are primarily concentrated in Sumatra and Kalimantan. The other half results from the spread of tilled land, especially yielding to rice paddies. Rice cultivation is, according to Hoscilo et al. (2011), also responsible for the loss of Kalimantan's peat meadows.

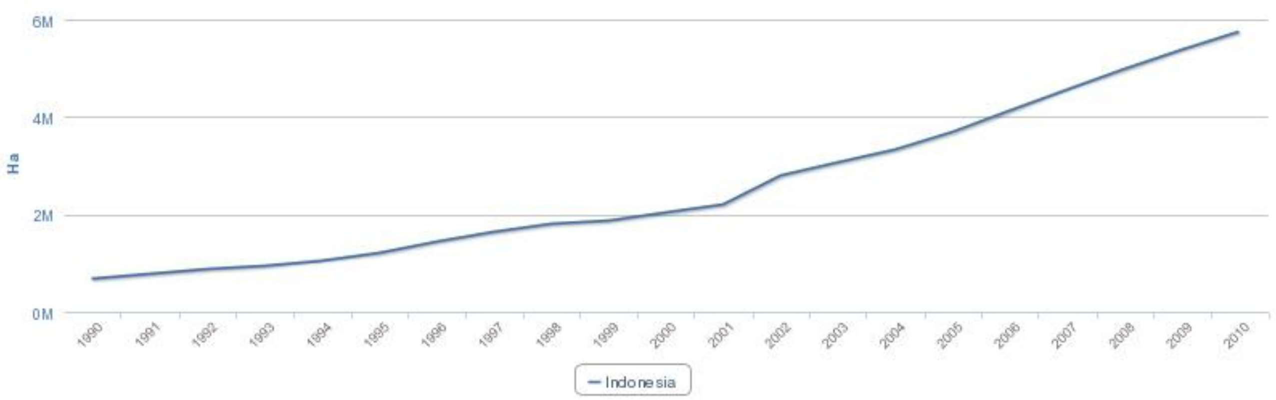

Figure 42: Indonesia Palm Oil

To sum up, it can be concluded: the study finds that mosaic type agricultural surfaces, as well as fallow land is mainly responsible for the diminution of residual areas in Indonesia. Where mosaic type agricultural surfaces are concerned, exclusively surfaces used for agro-forestry should be named. The diminution of mosaic-type surfaces results from the diminution of palm-oil plantations, perennial monucultures, as well as cash crop plantations. Both latter mentioned descriptions can include palm oil fruit. In smaller numbers, furthermore, peat meadows as well as abandoned lands are diminishing.

In Indonesia, land-cover change is above all characterised by the diminution of mosaic type agricultural surfaces, in particular of agro-forestry surfaces. Agro-forestry featured among traditional, small farmer agricultural systems, which was used in particular for the cultivation of cocoa and natural rubber.

This cultivation system was often presented in literature as a model of a sustainable agricultural form (Foresta, Michon 1994; Parikesit et al. 2005). Above all, high-carbon compounds and drought resistance, the considerable soil fertility, biological weed and pest control and even the improvement of biodiversity were attributed to this form of agriculture (Perfecto et al. 2005; Tscharntke et al. 2011). The conservation of the natural environment, but also the preservation of the cultural values of small farmers has hence been a matter of course. Agro forestry represented a promising alternative to subsistence economy, because profitable sales opportunities in the form of natural rubber, cocoa and coffee were created, whereas the ecological concerns for the natural environment were very insubstantial (Feintrenie, Levang 2009).

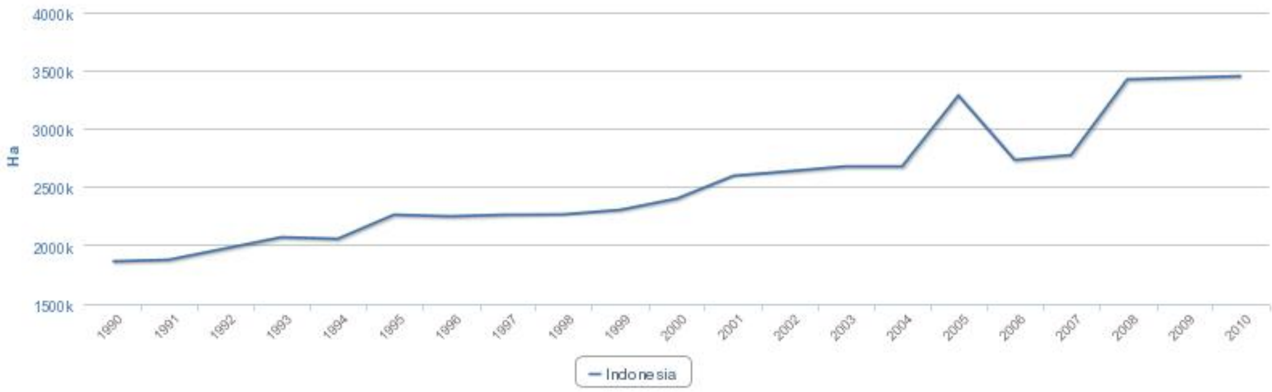

Figure 43: Natural Rubber Indonesia

Recent publications, however, take stock of the accelerating disappearance of this type of agriculture in favour of a trend of intensification and sprawl of agriculturally used lands, which is taking place in South East Asia and is responsible for the increasing decline of forest areas (Feintrenie, Levang 2009; Garcia et al. 2010). The reason for this is the integration of the national economy into the international market, which is exerting massive impact on the decisions of the local population to the detriment of agro-forestry. Compared to natural rubber, palm oil represents a much more profitable source of income, because it is applied to a large extent at international level and in many sphere of human life (Steffan-Dewenter et al. 2007; Feintrenie et al 2010). In this manner, palm oil is not only necessary for the production of food stuffs, where it is found in ice cream, cocoa and margarine, but is also used for soap, biodiesel and fertilisers. Furthermore, palm trees and palm oil fruits, unlike the plants of agro-forestry, are not planted singly, but in the form of plantations, which results in a far higher yield and clear financial incentives for Indonesia’s farmers. However, it is necessary to cast a differentiated look, because palm-oil plantations alone cannot be made responsible for the loss of residual areas in Indonesia. Also the increase requirements for other cash crops, such as coffee, increase the pressure on local land cover. The widening of national economy to include international export of palm oil, however, leads to Indonesia drawing the considerable consequences for land cover.

4.7 Nigeria

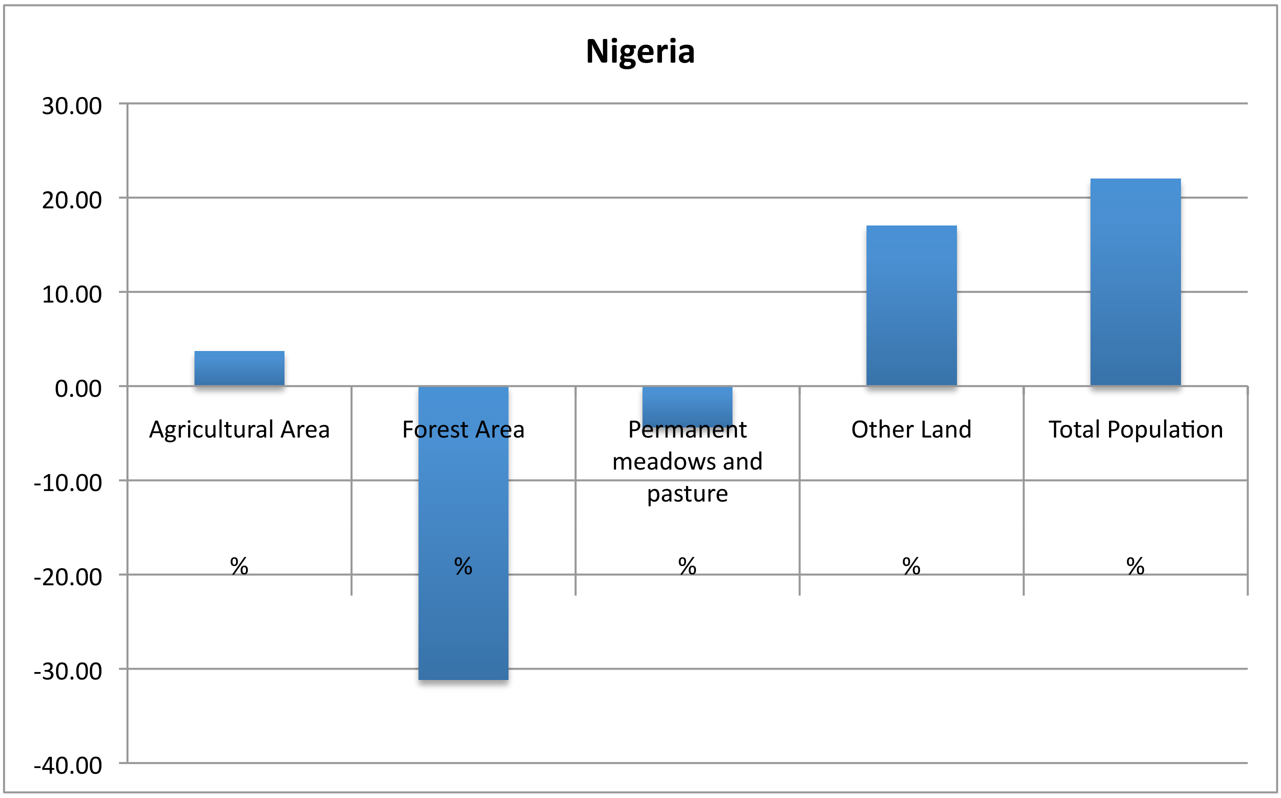

Figure 44: Land use change and population growth in Nigeria

Nigeria is today the most populated country of Africa and more than half of its population is living in poverty. Furthermore, Nigeria's population is ever growing.
The increasing population is one of the reasons for the slight increase in agricultural surface. However, Nigeria is, in spite of this increase in agricultural surface, not capable of sustaining itself; the average crop yield level is very low.

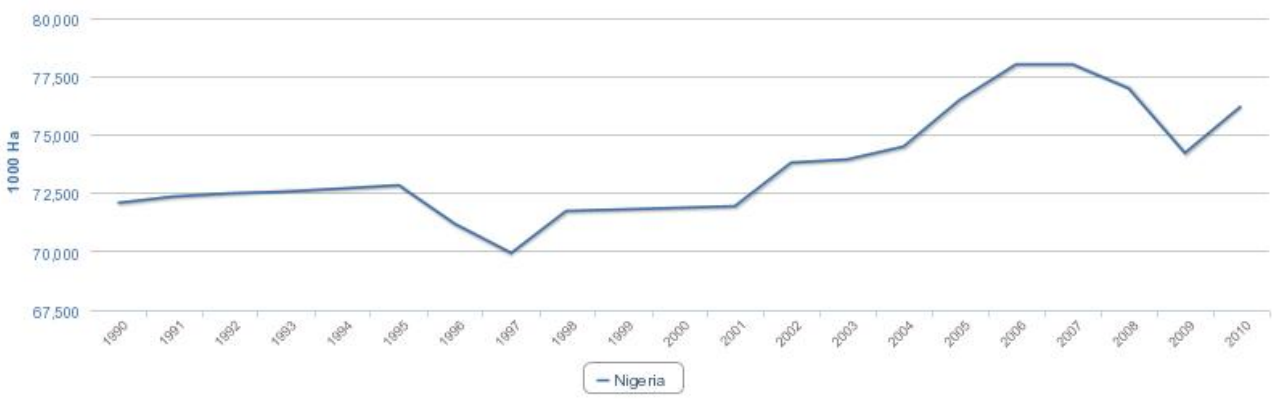

Figure 45: Agricultural Areas of Nigeria

Fig 46 makes this very clear:

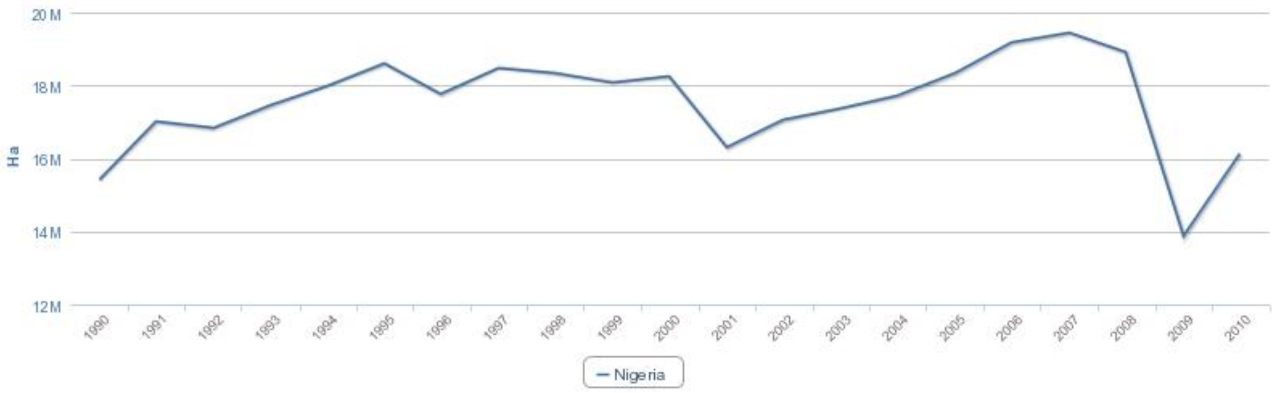

Figure 46: Cereals Total

Meanwhile, Nigeria has become the target of many foreign investors, who produce crops for export on large plantations. The increase of the surfaces, on which oil fruits are planted, shows this (Fig 41). As in Indonesia, oil palms are mainly planted. Nigeria is, furthermore, the fourth biggest cocoa producer in the world.

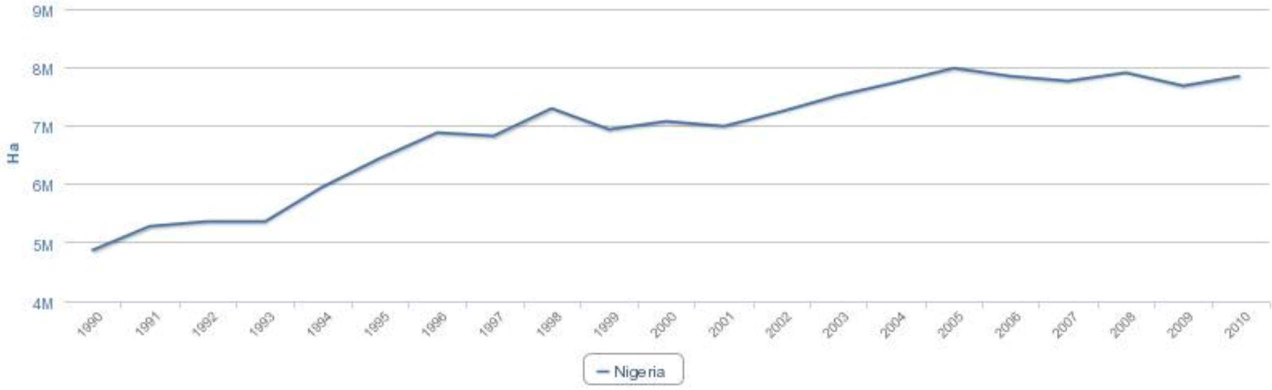

Figure 47: Oil crops Nigeria

Since, however, Nigeria's agriculturally used areas are also strongly affected by processes, such as desertification, this increase of agriculturally used land encroaches upon its forest area. As can be seen in Fig 48, the retrenchment of the forest area is to be considered as dramatic.

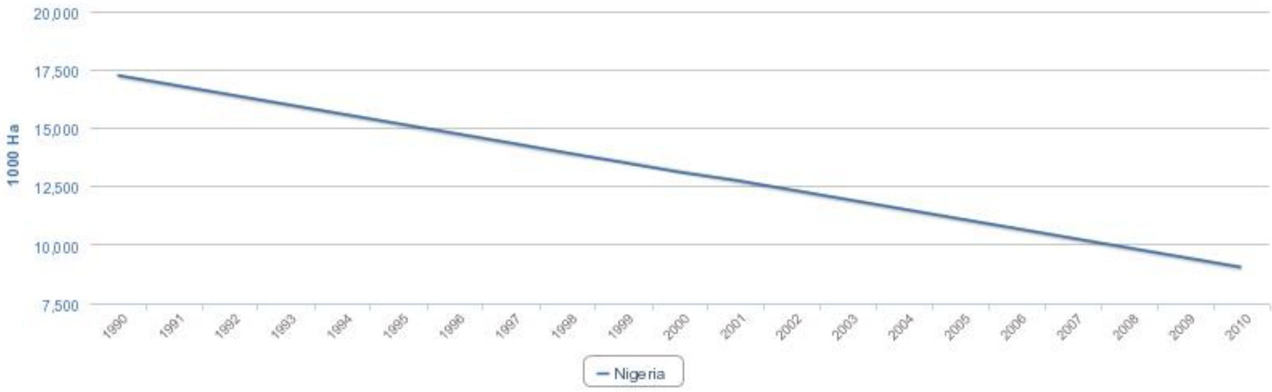

Figure 48: Forested Areas of Nigeria

The strong increase of the category other Land is to be explained above all by population increase, however, in this category, there are also surfaces, which are no longer counted as agriculturally used land as a result of erosion and desertification. Furthermore, infrastructural measures can be found there, whose coming about was imposed by the extraction of raw materials. Nigeria possesses large crude oil deposits, but also natural gas and lignite.

4.8 Poland

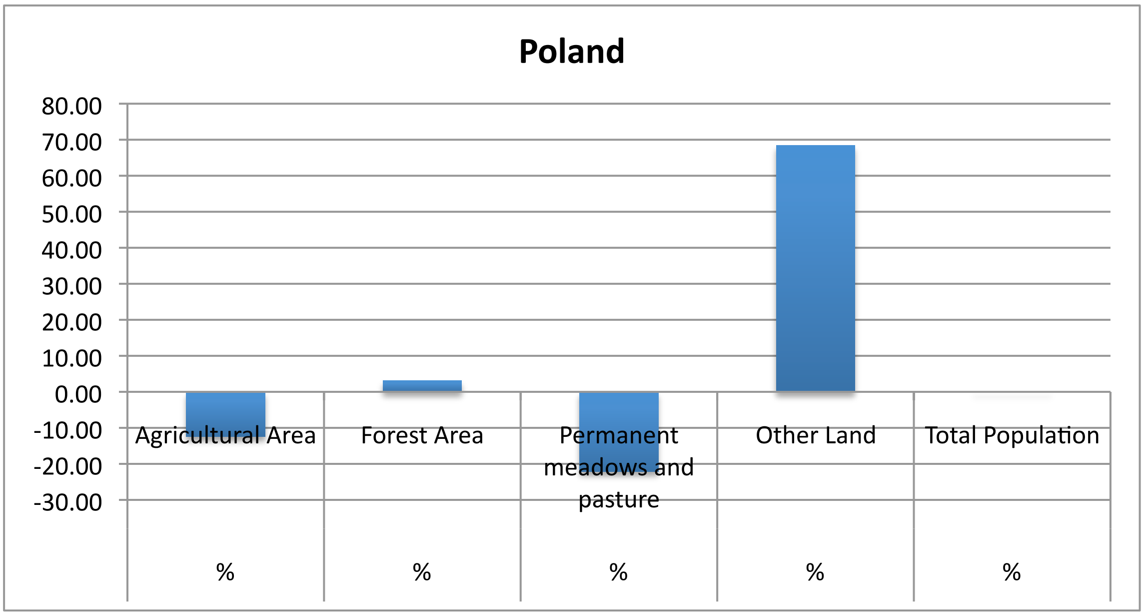

Figure 49: Land use change and population growth in Poland

The observation of Poland's long-term development clearly shows the evolution of that state within the European Union.
Poland's Population is stagnating, or rather, it is slightly declining. The massive investments in infrastructure measures as well as the implantation of industries and businesses in the past 10 years have lead to an increase of the category other land.
Before it's accessing the EU, Poland's agriculture was primarily comprised of smallholdings in many areas, which generated low yields in spite of extensive farming. On the other hand, as was the case in the ex-East German states, very well run farms on good agricultural sites.

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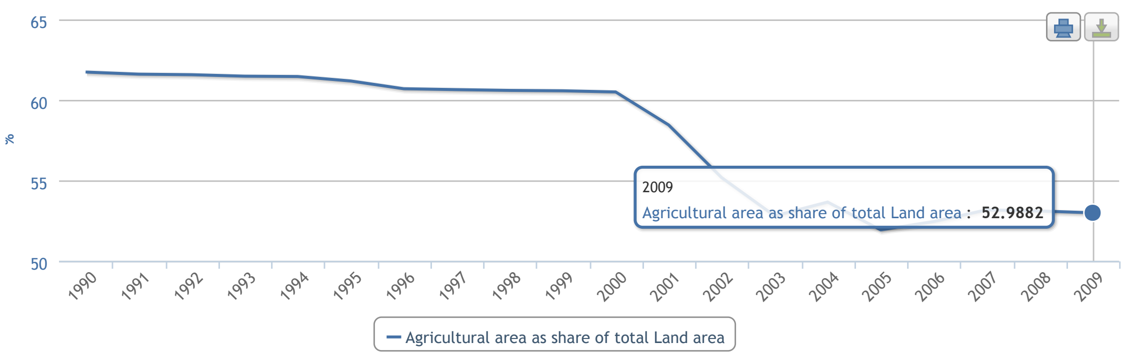

Figure 50: Agricultural area

Meanwhile, Poland possesses an intensive agriculture, whereas in many regions, the small-scale agricultural or sideline agriculture has been abandoned.

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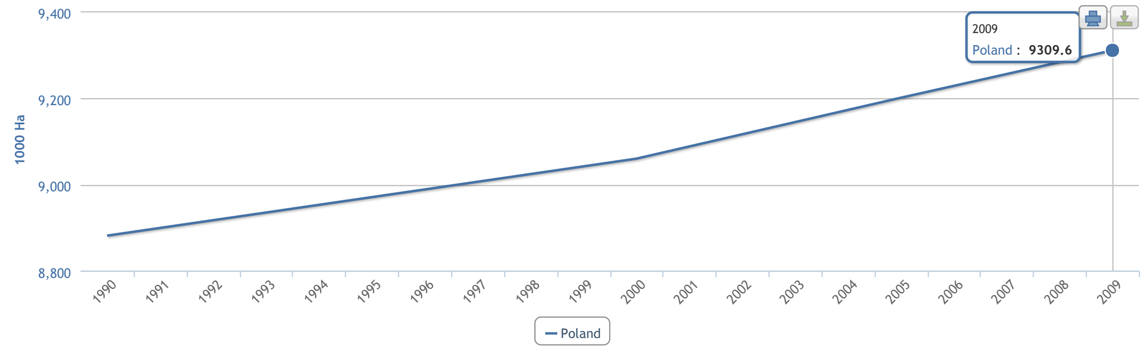

Figure 51: Forested Area

On the other hand, the forest area has been continuously increasing since the collapse of the Eastern Block. Since Poland is also the EU country, which has placed the largest proportion of its territory under nature conservancy, this explains the diminution of agricultural surfaces. Around 1% of Polish territory belongs to national parks. The designation of nature conservancy areas has lead to a slight increase of the forest area.

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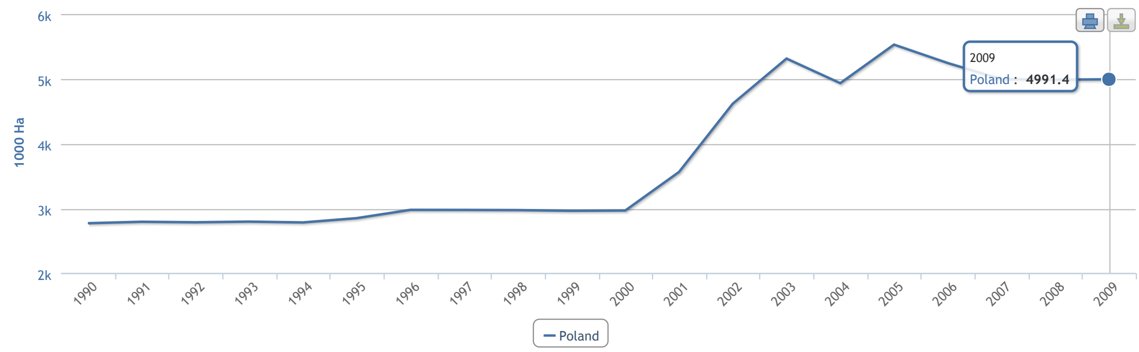

Figure 52: Other Land

The sector other Land is also strongly increasing. However, it also comprises all infrastructural measures, such as road constructions, settlements and business buildings. Poland accessed the EU in 2004, thereby opening the country to foreign capital, which flowed into agriculture and industry. The polish GDP was very high in the years 2003-2008, which can explain the increase of other land, especially the slight decrease since 2008. From 2007 to 2012, the Polish motorway and dual carriageway networks were massively extended.

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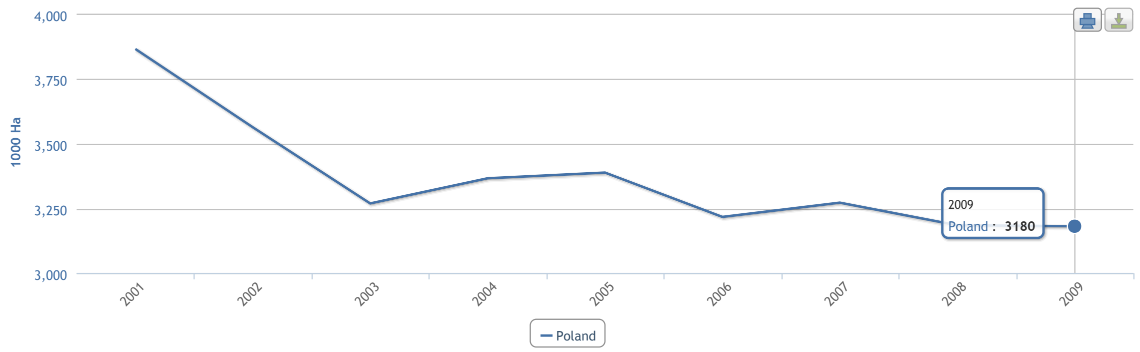

Figure 53: Permanent Meadows

Permanent pastures are also diminishing. Because of the changes mentioned above brought about a contraction of permanent pastures, not only transferred to agriculturally used area, but also to forest areas, and even also in the category other Land.

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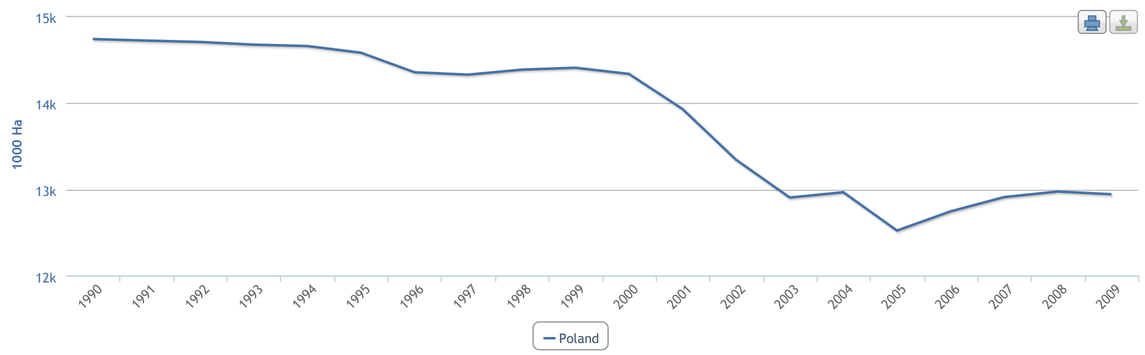

Figure 54: Permanent Crops

To conclude, it can be said of Poland, that the land-use changes are not a statistical problem, as formerly assumed, but a reflection of strong economic influences, causing border line sites, which are not good enough for agriculture, to be reforested and above all the influence of economic development on land changes.

4.9 Russia

Russia is the largest country in the world and is also interesting because Russia harbours all climatic zones, with the exception of the tropical one. However, because of this, and because of the bio geophysical environment, only less than half of the surface is agriculturally usable. This is the reason why Russia, only has access to around 70% of its own territory to put to agricultural use (Nehring 2008), compared to the US.

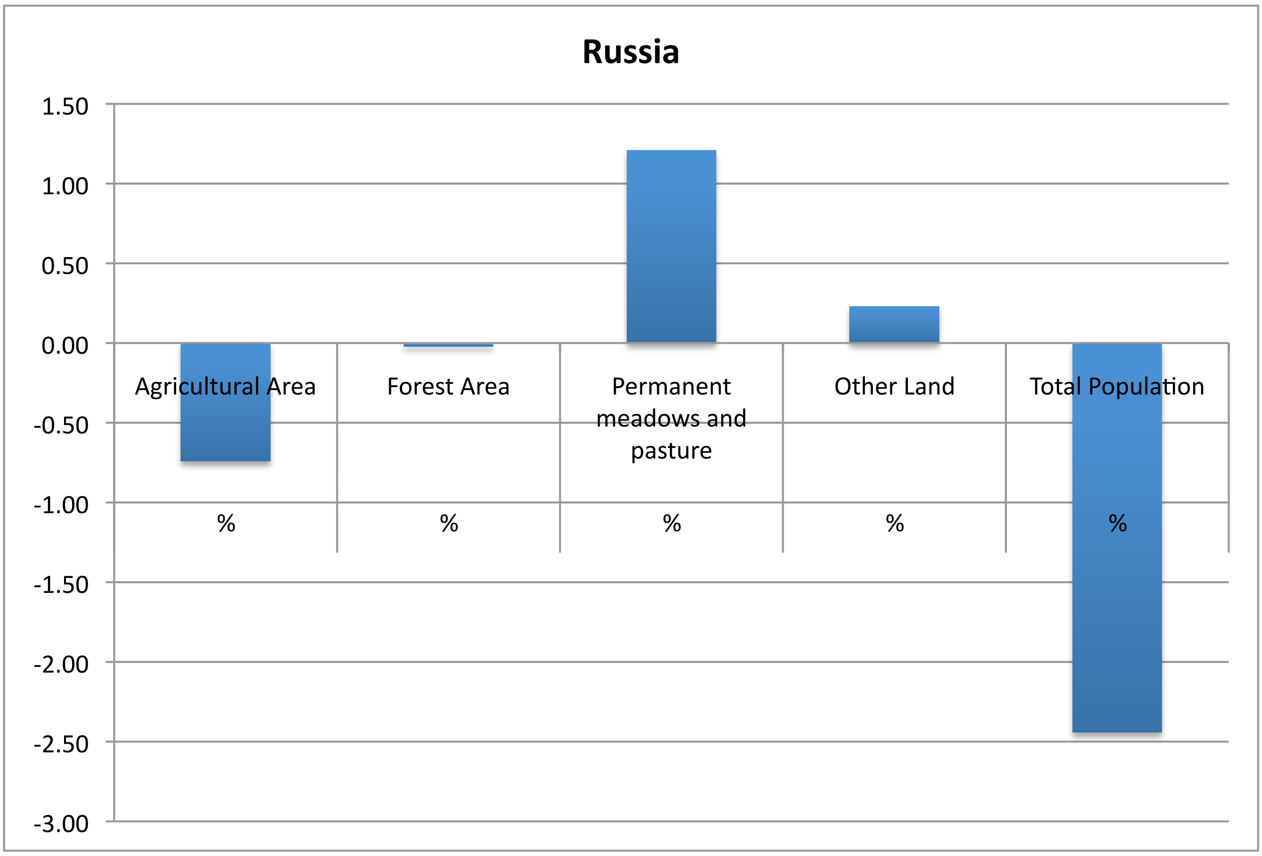

Figure 55: Land use change and population growth in Russia

It is furthermore notable that Russia's population has strongly diminished. Moreover, Russia is experiencing a rural exodus towards urban areas. In addition, Russia only has half the population of the US (Nehring 2008).

Russia has various forms agricultural exploitation, on the one hand a form of subsistence farming, private holdings, the successor farms of kolkhoses and Sovkhoses and, more recently, what is referred to as agricultural holdings. Private farms can certainly reach sizes and function with external working hands. The successor farms of kolkhoses are often structured as they were in the past, likewise, private holdings often lack the necessary capital (Nehring 2008). The development having led to the holdings, some of which spreading over 100,000 ha, which have been financed from various domains, pursuing mostly ambitious economic goals. This breakdown reveals that upheaval affecting agriculture in Russia. This can also explain the contraction of agriculturally used land. The more the agricultural structural change in Russia advances, the less agriculturally used areas will diminish in the future. This evolution can be compared with the situation in Poland. The level of crop yield, which Russia generates, is also interesting. It is just under one-third below that of the USA (Nehring 2008). This evolution of increasing yields per ha can be observed in Russia, as well as in Poland. The increase in the category other Land can be explained, on the other hand, by infrastructure measures and urban sprawl, as well as with the temporary or permanent abandonment of appropriate surfaces. Furthermore, Russia possesses great raw material resources, whose production has expanded in the past 20 years. The loss of forested areas is probably attributable to these factors. The increase of permanent pasture is also to be explained by the decrease of agriculturally used; here, surfaces are not put to use.

4.10 Sudan

Sudan is situated between 22° to 38° east longitude and 9 to 21° north latitude in the north east of Africa. From 2000 to 2009, however, Sudan was larger, because it then comprised South Sudan. The ex regions in the south are therefore included in the analysis. The climate is mainly dry and hot. The northern half is strongly characterised by the desert climate of the Sahara. The southern half is a transition from dry steppe climate to equatorial semi-humid climate. In order to conduct the analysis, the land cover description of Mayaux et al. (2004) is applied. Then, accordingly, Sudan is covered at the rate of around 47% with barren ground, 20 % agriculture, 12 % scrubland, 12 % open and sparsely vegetated grass areas, 5% forest areas, 2 % mosaics composed of forests and other vegetation, 1% wetlands as well as 0.1% thick forest areas. This distribution strongly deviates from the FAO distribution. According to FAOSTAT, agricultural surfaces cover over 50% of the territory; the forest areas cover less than 30 % and die residual areas less than 15 %. There is a vast difference in the proportion of agricultural surfaces.

Larger areas with barren and sparsely vegetated ground were probably counted as permanent pasture and meadows, because, according to FAO classification, these cover around 85% of agricultural surfaces. Scrubland, mosaic areas constituted of forests and other vegetation as well as wetlands, should they be covered in trees were possibly counted as forest areas. The relatively large residual areas (355,340 km^2, 2000) found in FAO-data can be assigned, as a consequence, to the sparsely vegetated surface, possibly only the barren surfaces. According to Mayaux et al. (2004), these would be sandy and stone-strewn deserts and dunes and sparsely vegetated semi-deserts.

The dry desert Sahara in the north the Sahel Zone immediately adjacent to it in the South constitutes Sudan's desert zones. The Sahara is characterized by sandy, barren soils. The hot dry dessert climate only allows sparce subsistence economy. In the Sahel Zone, the vegetation-scarce semi-dessert develops, in the south, into a scrub and tree savannah. As a result of the climatic variability, pastoral animal husbandry is the system mainly applied in that region. Mainly scrubland reaching down to the South East merges into the Sahel Zone in the middle regions. Migratory sheep husbandry merges into agro-pastoralism, in which rain-fed crops featuring mainly sorghum and millet mix with animal husbandry. The largest forest areas are situated in the South West. The dry sub-humid climate favours mixed farming for cereals and root crops. Particularly good prospects for agricultural growth have been predicted for this region
(Dixon et al. 2001; AFRICOVER 2003).

For the development of land cover in Sudan, a total of 5 articles could be identified. At first it was supposed that the diminution of residual areas in Sudan was mainly due to tilled and pasture land the dominant desert zone in the north has the largest share in the classification for the residual areas. Sandy landscapes, barren soils and sparsely vegetated areas were therefore particularly in the focus of the research and were analysed in regard to conversion processes. The results of Larsson (2002) and Fadol et al. (2012) do not confirm, at first, the supposition that desert has become smaller, on the contrary, they show an increase of sandy landscapes. For Larsson, sandy, cultivated and eroded / overgrazed surfaces increased in the east of Sudan, whereas grasslands decreased. The study by Fadol et al. (2012) shows a significant increase of cultivated and sandy areas, as well as a small increase in vegetation cover (partly scrubland). Peat soil with sand layers have, however, seriously decreased in size. Fadol et al. comes to the conclusion that the changes in land cover are signs of degradation and desertification and sees, in the encroachment of the sand, a danger for agriculture.

Larsson and Fadol's findings can be interpreted in the same manner with regard the decreased residual areas. Degraded land is increasing and is in various stages of degradation and desertification processes. The sand cover on peat soil indicates the beginning of degradation or desertification. However, the soil is still important for the development of new agricultural lands and could, as a consequence, decrease in size.

Sandy landscapes, on the other hand, will probably become agriculturally uninteresting and will be abandoned to degradation and desertification. Since, in Fadol et al's work, the reduced area of sand-covered peat is twice as large as the supposed sandy-soil surface, it can be supposed that that of the slightly degraded land can explain the diminution of the residual area. According to the residual areas classification, these would be the sandy landscapes, barren soils and sparsely vegetated areas.
The study by Biro et al. (2011) shows the increase of barren soils and sparsely vegetated surfaces, which point to an increasing degradation. His compilation shows a clear spread of mechanised agriculture in Central Sudan and a great loss of forest areas covered by scrubland. On the other hand, some cultivated areas transformed to unfertile soil and some forest areas in fallow lands. The increase in fallow lands, according to Biro et al. can be imputed to the decrease of soil fertility, which must be compensated by longer fallow times. Neither longer fallow times, nor the increase of barren soils and sparsely vegetated surfaces point to the decreased size of residual areas. It is rather the decrease of other forested areas (in the form of forest area covered with shrubs and bushes), which should be counted as residual surfaces. Before coming to this conclusion, however, it is necessary to give more details on land cover. However, the increasing degradation taking place on bare grounds and sparsely vegetated surfaces can endanger the availability of the land on agricultural surfaces. An increasing lack of land could, as a consequence, result in an intensification of agriculture.
The supposition that the current increase in agricultural surfaces is the result of the intensification of already existing agricultural surfaces, is supported by Sulieman (2010). His study comes to the conclusion that the current conversion of natural vegetation to agriculturally used lands has slowed down, because the availability of land for further agricultural expansion had reached its limits. It is the decrease of abandoned surfaced from shifting cultivation and secondary forests are proof of this. Not only abandoned surfaces from shifting cultivation, but also secondary forests exist with the frame of regeneration measures and are probably agriculturally used again at too a stage because shortage of lack of agricultural land.
In fact, leaving land fallow or abandoning agricultural surfaces is a typical measure of many farmers in the Sahel zone. This fact is supported by a further study by Suleiman et al. (2009) based on the local questioning of farmers of large holding, the reasons for vegetation changes were analysed. The main factors given by the farmers are soil degradation, crop rotation, monocultures and the short duration of the rainy season. Abandonment of land, for the persons asked, fulfills the role of soil regeneration and weed control or is the result of lack of rain and financial means. The rehabilitation of the degraded surfaces is all the more effective as the period lasts long. On the one hand, periods of 5 to 10 years are indicated. On the other hand, many farmers use the short fallow times of between 1 and 5 years. The shortening of the fallow-land period was would, in the end, explain the decrease in residual areas. In summary, it can be derived from the study findings that bare soils, sparsely vegetated areas and surfaces abandoned from shifting cultivation might be responsible for the decrease, degrading or desertification of residual areas as well as other forested areas. Furthermore, because of the shortening of the duration of some fallow periods, some fallow land has been taken into the classification of agricultural land.

4.11 USA

Even though, in the USA relatively insignificant land-use changes have been recorded, and population growth is also not overly high, the USA have been included in this countries analysis because of their importance not only as a state with a large surface, but also as global player in agriculture.
The insignificant land-use changes during the period of study result mainly from the fact that the American change in agricultural structure is basically compete. This is impressively demonstrated by the data on the number of farms. Thus, the number of farms in has dropped by 2/3 from 6 million to almost 2 million the last 50 years. The mechanization and intensification during this

period made for a doubling of income at a reduction of agricultural professionals by around 11 million to 1.2 million workers today (US Embassy 2008).

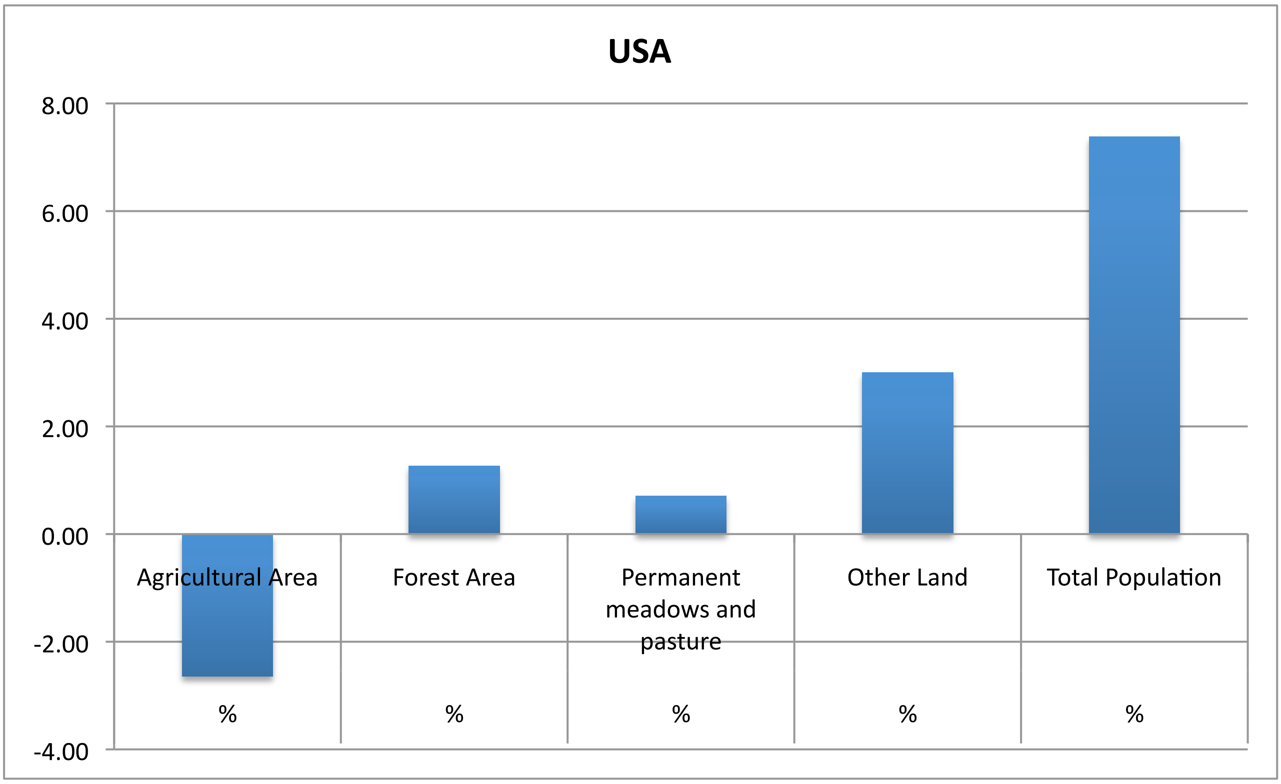

Figure 56: Land use change and population growth in USA

As shown on Figure 56 the level of land-use changes in forest areas and Permanent pasture is between 1.2 and 0.8 %. It shows that the loss of agriculturally used land has shifted to this category. At the same time, the category other land, which can be explained as Infrastructure measures, municipal and commercial buildings, as well as raw materials. In principle, the USA experienced little significant changes in the past 10 years.

4.12 Summary

Considering the analysis of the single states, it becomes obvious that it is impossible to identify a single driving force as cause for land-use changes. Rather, in all examples, many driving factors are working together. So, first and foremost, population development should be named as main driving force. Further, economic development and the evolution of the average wage per head play an important role in taking over surfaces because of per-head nutrition needs. Here, it is very the influence of a change in calorie composition on this area's utilisation.

However, not only in Argentina but also Brazil, political insturments can be shown to be the causes of land-use changes with regard to the production and utilisation of bio fuels.

Generally, the so-called cash crops, that is to say, the marketable fruits, who were traded internationally, would also have a great influence on land use. Especially in countries, such as for example Indonesia, these plants, or their products are an important source of foreign currency.

Indirect land use changes cannot be illustrated with the data collected.

Notably, due to a lack of data the no land-use change can be directly imputed to raw-material production. In some regions, this is possible in a specific analysis (see Büsse, 2012), the effects are no longer attributable at the time of analysis.

Land degradation and the deterioration of soil cannot to be analyzed in the examined records. Looking into single countries of Central Asia, Africa or even Australia, the problematic seems to come to the surface. However, it is not possible to identify it clearly.

Land-use changes are, therefore, the result of a series of various causes, which can mutually intensify, but cannot be clearly identify as single cause.

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