

Research on Sustainable Land Use in Germany and India – Future Tasks

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Introduction

Germany and India are strategic partners for cooperation and research. Thousands of researchers have been working in the respective partner country on a variety of topics and disciplines. Joint agendas in land use research in India and Germany are only a few but the topic is emerging. The present paper will provide an overview on the major trends and tendencies of agricultural land use research in both countries. We hereby focus on agriculture and forestry and start our contribution explaining some general and common concepts of land use research. We conclude with a set of possible issues for a joint research agenda taking into account country-specific research interests and experiences, their strengths and weaknesses.

Investigating land use and land use changes

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO 1997). It is a dynamic process that underlies a continuous development. Long term land use change is induced by many factors including population growth and industrial development. The related growing demand for infrastructural area and areas for the primary production of food, fibre and energy results in a growing scarcity of fertile land. Land use and land use changes directly affect the exchange of greenhouse gases between terrestrial ecosystems and the atmosphere (IPCC 2000) and, together with use of fossil fuels, are considered as the major anthropogenic sources of carbon dioxide.

Agricultural systems, their impacts and changes often include a very specific human dimension. We may speak of beneficiaries and victims of change. In the following we would like to present some concepts from the field of land use research.

Concepts of agricultural land use research

The idea of *Ecosystem Services* reflects the assumption that efforts and interventions to manipulate agro-ecosystems in order to meet specific production functions represent certain costs to the rest of the ecosystem. These costs can be expressed in terms of energy, matter and biological diversity, and often negatively affect goods and services that so far were considered to be free and abundant. Services such as nutrient cycles or the biological control of pests provide the biophysical necessities for human life or otherwise contribute to human welfare.

Another famous concept is the *DPSIR* framework that is applied e.g. by the European Environmental Agency (EEA) and the United Nations Environment Program (UNEP). This framework assumes cause-effect relationships between interacting components of social, economic, and environmental systems, which are¹:

- **Driving forces of environmental change** (e.g. industrial production)
- **Pressures on the environment** (e.g. discharges of waste water)

¹ <http://www.unep.org/dewa/assessments/ecosystems/water/vitalwater/12.htm#13>, last access 11th of July

- State of the environment (e.g. water quality in rivers and lakes)
- Impacts on population, economy, ecosystems (e.g. water unsuitable for drinking)
- Response of the society (e.g. watershed protection, cleaner production)

Driving forces lead to a certain pressure on the environments leading to a certain state. The impacts of this state affect society which responds to the case e.g. with a conservation effort.

As a variety of demands and land use options are available the concept of *Multifunctionality* of land use is widespread. Indicators to link the socio-economic requirements with the landscape potential were developed (e.g. Wiggering et al. 2006).

As agricultural land use involves a variety of disciplinary knowledge a transdisciplinary approach is required. Transdisciplinary studies on sustainable agricultural land use cannot be solved by one or even a few points-of-view. They gather a wide range of stakeholders including academic experts, field practitioners, community members, political leaders, and entrepreneurs among others to solve some of the pressing problems facing the world, from the local to the global.

Environmental impacts of agricultural land use

The negative impacts of agricultural land use on natural ecosystems, soil pollution and degradation, deforestation, erosion, consumption and pollution of water are well studied (e.g. McLaughlin and Mineau 1995; Lundekvam et al. 2003). The historical conversion of natural systems to agriculture has resulted in a net release of carbon dioxide to the atmosphere, determining alteration in the climate, and the biogeochemical cycling of carbon, nitrogen and other elements at a global scale (Schneider 1989; Houghton 1995; IGBP-FIDP 1995). On the other hand, these global changes may be probably inducing new shifts in land use by means of feedback mechanisms that are still poorly understood (Viglizzo et al. 1997). Climate change is expected to force farmers all over the world to develop adaptation and mitigation strategies for sustaining agricultural and silvicultural production.

Socio-economic drivers must be taken into account while analyzing future land use development as there are: population growth, economic growth, changes in demographics, agricultural and forest prices, regional and local planning and politics including social and institutional frameworks. What is also to be recognized is the differential impacts of 'key drivers' land use/cover changes that impacts on a larger scale (policy dimensions and market pressures, both national and international) as distinct from lesser impacts at the local level, the 'proximal drivers' arising at the local level from people living in the region (Indian National Science Academy 2001; Lambin et al., 2001). Indeed, these drivers differ in their intensity according to the natural and socio-cultural conditions and are highly site-specific.

Agricultural land use research

Given the above mentioned scenarios, sustainable land use and research has to provide problem-oriented and location-specific applicable solutions to society focusing on long-term resource availability. The well-known concept of "sustainability" is regarded a must in that context. It is of key interest to which landscapes the agricultural practices are leading.

Governance-oriented agricultural land use research can be divided in ex post "What happened in the past?" and ex ante "What may happen in the future?" approaches and a combination of both. To analyse land use systems in a way that adequately targets the multidimensionality of possible situations and the implications of certain changes a broad bundle of scientific disciplines come into action. Not only the "classical" agricultural and forestry disciplines related to production technology, soil and crop science, plant nutrition and pest management are required. Neighbouring disciplines such as geology, biology, ecology and meteorology but also social sciences such as economy, politics, law, sociology and

cultural studies are needed to master this task. These are increasingly represented in the land use/land use change research community.

The analysis takes place on different spatial levels and scaling up of static or dynamic situations is frequently done. Apart from the typical disciplinary approaches a large variety of methods and theories are therefore applied in land use research. Large multidisciplinary studies such as the Millennium Impact Assessment (MIA)² and the Global Biodiversity Assessment (UNEP 1995) involving thousands of scientists help us to understand the current environmental situation on a global scale. The Global Land Project (GLP)³ initiated by Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP) targets the (1) Dynamics of Land Systems, the (2) Consequences of Land System Change and the (3) Integrating Analysis and Modelling for Land Sustainability. The urban and peri-urban context is also addressed in agricultural land use research as pressures in rural areas lead to migration and increased urbanization patterns. The "Emerging Megacities Project"⁴ with a study in Hyderabad, India may serve here as an example.

² www.millenniumassessment.org, last access 11th of July

³ www.globallandproject.org, last access 11th of July

⁴ www.emerging-megacities.org, www.sustainable-hyderabad.in, last access 11th of July

Land use and sustainability research in Germany

According to the European CORINE (Coordination of Information on the Environment) land cover project roughly 54% of the total area of Germany is agricultural land while forestry counts for another 30%. Additional 4% are covered by national parks or further categories of protected areas while only 12% are classified as building area. BMELV (2003)⁵ states that the share of the agricultural sector at the total GDP is less than 1.5 % while work force accounts for 3.2 % of all employees. German agriculture has a strong political lobby. Forestry and agriculture are increasingly engaged in energy production. FNR (2008)⁶ figures that in 2008 energy crops were produced on 2 million ha representing roughly 17 % of the country's agricultural area.

The separation of Germany into two contrasting economic systems between 1949 and 1990 has led to two contrasting farm types that dominate the regions. Family farms around 25 ha size are typical for the western states dominated by small structured landscapes. Agricultural enterprises with average farm sizes above 200 ha including single corporations that manage several thousands of hectares prevail in eastern Germany⁷. A decrease in both farm employment and the numbers of farms is documented while many of the remaining ones have increased in size, productivity and specialization. This trend has led to a reduction of the product variety and the establishment of the economic branch of agricultural contractors. These offer a variety of services from harvest to tillage and field management and have become important partners to farmers enabling them to benefit from scale effects.

Policy as the major driver of German Agriculture

Agricultural markets in Germany are highly influenced by the policy framework within the Common Agricultural Policy (CAP) of the European Union. The CAP expenditure still covers more than 40% of the whole EU budget (IEEP 2009)⁸. This legislative framework which is implemented by the Member States is based on two pillars that support and coordinate agricultural production, rural development and environmental protection related to agriculture. Pillar I is mostly known for direct payments related to the agricultural production activities that are tied to basic requirements concerning food safety, animal welfare and environmental protection also known as Cross Compliance. Pillar II known as rural development provides a bundle of incentive based measures such as agri-environmental programmes, compensation payments, trainings and other support to farmers. Changes in the policy framework are reflected in the production systems and the landscape appearance, a process that has been made quite clear through the "yellowing" of Germany's landscapes by *Brassica napus*, a subsidized oil seed crop for bio-energy production.

Impacts of German Agriculture on the Agro-Ecosystem

High-input agriculture along with the use of heavy machinery, larger parcels and narrowed crop rotation has led to negative impacts on the environmental services. Losses in biodiversity, increased erosion, pollution of ground and surface waters and a decrease of certain land use functions such as recreation are documented. The European Commission considered agricultural soil degradation as one of the principal environmental problems of Europe⁹.

⁵ www.bmelv-statistik.de, last access 11th of July

⁶ www.fnr-server.de/cms35/index.php?id=140, last access 11th of July

⁷ www.geographie.uni-marburg.de, last access 11th of July

⁸ www.cap2020.ieep.eu/2009/6/26/cap-to-competitiveness, last access 11th of July

⁹ www.ec.europa.eu/environment, last access 11th of July

Research on sustainable agricultural land use in Germany

The aims of planning and development of land resources in Germany are to improve the management of human settlement, conservation of natural goods and the support of the "Good Agricultural Practice". Some of the major fields of agricultural land use research in Germany are:

- *Basic research* (e.g. nutrient cycles, organic matter fluxes, landscape dynamics)
- *Climate change and agriculture* (e.g. gas emissions from agricultural areas, fens)
- *Impacts on public and private health* (e.g. soil, groundwater and air quality)
- *Sustainable production practices* (e.g. conservation tillage, precision agriculture)
- *Traceability systems in the food chain* (e.g. systems, feasibility)
- *Sustainable bio-energy production* (e.g. impacts, conflicts, values)
- *Structural change in rural areas* (e.g. integrated rural development)
- *Environmental standards and quality management* (e.g. cross-compliance, certified food)
- *Multifunctionality of land use* (e.g. urban–rural interfaces, energy and agriculture)
- *Policy related research* (e.g. acceptance and adoption, planning tools, policy analysis)
- *Rural sociology* (e.g. migration, gender issues, employment)

In Germany today 11 Universities and 13 Universities of Applied Sciences offer academic education in agriculture and related fields. Agricultural research in Germany is facing serious problems mainly due to budgetary issues. The German Board on bio-economic research (BioÖkonomieRat)¹⁰ concluded in July 2009 that bio-economy has to provide solutions regarding the global challenges of climate change, food security and energy supply and that the sector therefore needs to be strengthened.

Land use and sustainability research in India

India's main environmental problems are pollution, waste management and land degradation. India's food production heavily increased during the *Green Revolution* apart from the 1970s that broadly introduced high input agriculture. In parts, this led to homogenized landscapes and large ecological losses. Social conflicts related to agriculture are still reported and food security is remaining a major topic.

Driving forces for land use changes in India

In the following, we will provide an overview of some major ecological and socioeconomic drivers for agricultural land use changes and their impacts on the most common land use systems in India.

Climate Change

Not all possible consequences of climate change are yet fully understood, but the three main 'categories' of impacts are those on agriculture, sea level rise leading to submergence of coastal areas, as well as increased frequency of extreme events. Each of these consequences poses serious threats to India (Parikh and Parikh 2002). Changed patterns in temperature and precipitation are expected. Considering a range of climate change scenarios which project a temperature rise of 2.5 °C to 4.9 °C for India, Kumar et al. (2001) concluded that without considering the carbon dioxide fertilization effects the yield losses for rice and wheat would vary between 32 and 40 %, and 41 and 52 %, respectively.

¹⁰ www.biooekonomierat.de, last access 11th of July

Population Dynamics

Among the socioeconomic drivers affecting land use demographic patterns are considered of key importance. Providing a sufficient supply of food and fibre for an increasing number of people poses an immense pressure on the remaining ecosystems. Across India, the estimated population for 2009 ranges around 1.17 billion people of which 27.8 % (Census of India 2001)¹¹ are living in the cities. Population growth rate is estimated around 1.3 % (US Department of State 2009)¹² what stands for an increase of roughly 17 million people per year. The extensive use of fuel wood, mainly for cooking, has contributed to the high levels of airborne particulate matter and has contributed to depleting the forest cover around most Indian cities (Taylor 1996).

Economic Growth

The growing national economy in India embedded into global markets and economies shows a growing demand of suitable land for infrastructure and energy among other needs. Coal is still the major source of energy and CO₂ emissions (Parikh and Parikh 2002). The emergence of industrial centres was not reflected in adequate pollution control mechanisms.

Environmental Politics and Policy implementation

Forest resources are mostly covered by the Forest Conservation Act from 1980, amended 1988, the National Forestry Action Programme (NFAP) founded in 1988 and the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. Restrictions of land use in some occasions have led to conflicts between villagers and the state or reserve authorities leading to such dramatic measures as resettlement of villagers from certain protected areas to areas outside a wildlife sanctuary (Karanth 2007). Many scientists concluded a better acceptance of protection schemes when participatory management approaches including the local population were pursued. Further studies (e.g. Das et al. 2006) provide an identification of zones most valuable for conservation for a more effective conservation planning. Case study approaches provide on the ground comparisons of different protection regimes and their impacts on varying sets of indicators (e.g. Nautiyal and Kaechele 2007). Conservation approaches in India are applied under the paradigms of sustainable use that favours the gentle use of natural resources under the principles of sustainability or the conservation paradigm that supports the restriction of certain forms of land use in 'protected areas' (Madhusudan 2003).

Culture

The conservation of natural areas has a very old history in India. The concept of "sacred" biota and abiotic elements is known for several thousand years (Sinha 1995). Sacred groves are spread across the country and Malhotra (1998) estimated their number from 100,000 to 150,000. They form an integral part of the Indian landscape. Although some authors expressed critics that religious feelings do not longer detain rural dwellers from certain activities such as hunting (Madhusudan and Karanth 2002) sacred areas often remain as islands of biodiversity within highly degraded landscapes. But Chandrakanth et al. (2004) concluded that further governmental support is needed to strengthen the traditional village organizations in efforts to conserve the sacred groves in southern India.

Agricultural Land use Systems and their impacts in India

India is ranked among the mega diverse countries in the world (Shi et al. 2005). The country aims at maintaining and conserving its biodiversity while providing food security to its

¹¹ http://www.censusindia.gov.in/Census_Data_2001/India_at_glance/rural.aspx, last access 11th of July

¹² <http://www.state.gov/r/pa/ei/bgn/3454.htm>, last access 11th of July

inhabitants. About 4.9 % of the total land surface is under protection. According to the *Köppen system* for climate zone classification, India covers six major climatic subtypes, ten bio-geographical regions, and as much as 29 different agro-ecological zones (Subramaniam 1983) are distinguished. Except the northern mountainous region perennial agriculture is practiced throughout the country generating two to three harvests per year depending on the monsoon patterns. According to ADB (2005)¹³ more than 30 % of Asia's irrigated land is in India, around 59 million hectares. Large amounts of the total area under cultivation in India are considered as substantially degraded. Timber extraction and the conversion of forests into agricultural lands including plantations (rubber, coffee, palm oil etc.) are having a strong impact on India's agro-ecosystems.

Land management systems vary from subsistence farming to intensive production systems. Low input farming systems are characteristic for e.g. the mountainous landscapes of the Himalaya and the Western Ghats. This rain fed agricultural systems are usually highly dependent on forest resources (e.g. fodder, straw, timber wood). Problems of land degradation due to overexploitation of land and forest resources are reported. Therefore, Nautiyal and Kaechele (2008) studied the impact of replacing firewood by liquid gas to lower the pressure on agro-ecosystems. The "Traditional Ecological Knowledge" (TEK) on forest management and community-based participatory forestry systems (Ramakrishnan 2007) is also receiving attention. The social and cultural dimension of land use, religious and gender topics related to land use and the use of medicinal plants are receiving increasing attention.

Intensive agricultural production systems basing on mineral fertilizer, application of pesticides with an increasing share in GMO varieties are prevailingly found in the *Gangetic Plains*. The plains that border the southern foothills of the Himalayas are the most productive agricultural area of the country. The intensive production systems are highly dependent on the water resources from the Himalayan region and are affected by changes in climate or land use patterns in the uplands. In the densely populated area population pressure is strong. Gopinathan and Sudhakaran (2009) document the competition between different forms of land use including bio-energy production which is influenced by the international markets. *Central India* is dominated by *semi arid conditions* with low precipitation and poorer soils in comparison to the Gangetic Plains. It is highly dependent on irrigation.

¹³ <http://www.adb.org/Water/actions/ind/irrigation-reforms.asp>, last access 11th of July

Implications for Indo–German land use research in India

Several future tasks for joint Indo-German approaches in the field of agricultural land use research in India can be identified. The climate change debate, the United Nations Millennium Development Goals on poverty reduction, the Convention on Biological Diversity and many other agreements remind us on our joint responsibilities for the earth ecosystem and its people. It is a particular achievement of climate change research to have spread the message that it does matter to other parts of the world what is done elsewhere.

Joint approaches of Indo-German teams in land use research in India should aim at cooperative ways of equal partnerships. In applied sciences the institutional structure of the research process is crucial for generating solutions that can be accepted, implemented and sustained by local stakeholders. An exchange of knowledge on technology, methods and theoretical concepts is regarded as potentially fruitful in a variety of fields which we may not prioritize.

We would like to encourage research related to the environmental impacts of agricultural land use systems. Methodologies should include participatory and community based approaches as well as economic, policy and institutional analysis, scenario development and modelling. Emission of greenhouse gases and adaptation and mitigation strategies to climate should be a major target of a holistic approach. The understanding of cultural landscapes and value systems should play a major role in the analysis of local situations to support socially and culturally acceptable solutions. Ecologically sound agricultural production technologies in line with improved production patterns are needed for the extensive agricultural systems. Traditional Ecological Knowledge (TEK) should be conserved and applied. Precise control and reduction of inputs while introducing a set of conservation measures (e.g. Precision Agriculture, Conservation Agriculture, and organic Agriculture) are promising approaches for the intensive systems. We may consider recycling strategies for organic matter and soil fertility management as key instruments towards non-polluting agriculture. A recent area of interest is the economic, ecologic and social dimension of bio-energy production. Hereby the identification of appropriate production systems including agroforestry systems and fast growing tree species within agricultural crop rotations and the integration of these systems within the local and regional context of energy and agricultural production is to be addressed. The conservation of agro-biodiversity, research in medical plants and afforestation are needed. Multifunctional land use approaches such as the recultivation and restoration of degraded areas, open-cast mining areas and transformation of these areas into recreational sites may be a further promising field of work.

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