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# India 2050: scenarios for an uncertain future

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# Rapport in het kort

## India 2050: scenario's voor een onzekere toekomst

India vervult een steeds belangrijker rol in de wereldeconomie – en daarmee samenhangend in grondstoffengebruik en uitstoot van stoffen. Het modelinstrumentarium om de kansen en bedreigingen voor India en voor andere delen van de wereld als gevolg van deze ontwikkelingen conceptueel te verkennen is echter beperkt. Dit rapport verkent de mogelijkheden om hierin verbetering te brengen, met name met het oog op de grote heterogeniteit in India die moeilijk in geaggregeerde gegevens tot uiting komt.

Modelgebaseerde berekeningen wijzen op een bevolking van meer dan 1,5 miljard mensen rond 2050; deze groei van met name jongere en beter opgeleide bevolkingsgroepen is één van de aandrijvers van de economische groei. Vooruitberekeningen met het demografisch model PHOENIX en het IFs Economy model laten zien dat een dergelijke gelijktijdige groei van bevolking en welvaart kan plaatsvinden mits er voldoende en tijdig wordt geïnvesteerd in gezondheidszorg en onderwijs. Uit aanvullende berekeningen, onder meer met het TIMER energiemodel, blijkt tevens een niet geringe kans op ecologische en sociaal-economische beperkingen voor een dergelijk ontwikkelingspad. Een werkelijke verbetering van het welzijn van een groot deel van de Indiase bevolking zal dan ook afhangen van het tijdig realiseren van de benodigde investeringen in gezondheidszorg en onderwijs en het duurzaam ontwikkelen van India's hulpbronnen (land, water, energie) – met visionair en krachtig overheidsbeleid als onmisbaar onderdeel.

Trefwoorden: India, scenario's, duurzame ontwikkeling

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# Summary

In the last decades, there have been large demographic and economic changes in India, a country where one out of every six people in the world live. The major long-term trends identified in this and other reports project an increasing role for India in the global economy and, correspondingly, in resource use and emissions. However, the tools to explore the opportunities and threats for India and for other parts of the world as a consequence of this development suffer from conceptual limitations, which are particularly evident in terms of the large heterogeneity of India, which is difficult to capture in aggregate average data. This report explores options for improvement.

Among trends shown in India during the second half of the 20th century, the most important are: a declining but still large rate of population growth; a successful improvement of the food situation with constraints emerging for further expansion; a rapid but unbalanced and unequal economic growth since the 1990s; a rapid growth in energy and water demand that can only partially be met.

The official projections for India expect a slowly stabilizing population and a sustained high rate of economic growth for the next three to five decades. Model-based simulations suggest a population of over 1.5 billion people by 2050, with an increase in the size of the younger and better educated population being one of the drivers of economic growth. These projections presume adequate investments in health care, water and sanitation and education – hence, also an adequate tax base and governance and institutional context. These expectations imply a significant increase in the average level of the standard of living.

Forward calculations with the demographic model PHOENIX and the International Futures (IFs) Economy model show that such developments of population and income are possible, provided that sufficiently and timely investments in health care and education take place. Additional model simulations, among others with the TIMER energy model, indicate that ecological and socio-economic constraints might bar these positive developments and drive the country into other directions. Of particular importance in this respect are the reliable provisions of sufficient food, water and energy of sufficient quality. Another important challenge is to appropriate livelihoods and incomes that enable poor agrarian populations to access these basic amenities in an increasingly market-linked economy. A real increase in well-being for a large part of the Indian population will therefore depend on appropriate and timely investments in education and health and on sustainable management of India’s resources (land, water, energy) – with visionary and strong government policy initiatives being necessary to achieve this.

An exploratory analysis of a number of future developments in India with the Ifs-model shows that a stabilization in the population at an income level comparable to that of present-day Western Europe is in principle possible. The analysis also indicates, however, that a number of possible feedbacks from the environment (pollution of air and water, climate change) and preconditions to be met in the areas of taxation and governance are so uncertain, that the conclusions of the available model outcomes should be considered with caution. It

turns out that even in these optimistic forward projections the aspirations expressed in the Millennium Development Goals (MDGs) are (too) high.

The conclusion drawn in this report is that more (model-based) research is needed and that this research should focus on the nature of the (aspired) economic growth, on the required size and nature of investments in health, education and other (land, water, energy, transport) infrastructure and on the potential feedbacks and impacts from the environment. Only by adopting this approach will tools become available which have the potential to form the basis for carrying out meaningful long-term assessments of the developments in this – in global terms – increasingly important country.

# Acknowledgement

We would like to acknowledge the input from Barry Hughes and Haider Khan of the University of Denver, both during and after the workshop at MNP in June 2006. Many thanks to Arindam Mandal who helped process and validate the I-O data set for India that was used in this analysis. The discussions with researchers at the Indian Institute of Science in Bangalore, at the Indira Gandhi Institute of Development Research in Mumbai and with members of the Balaton Group during the Annual Meetings have deepened our insights. We thank Detlef van Vuuren and Morna Isaac for the permission to use the recent energy scenarios and Bas van Ruijven for the shared travel experiences and discussions in the spring of 2006.

# 1 Introduction

The Netherlands Environmental Assessment Agency (MNP) supports national and international policymakers by analysing the impacts of societal trends and policies on the environment. Within this framework, one of the major aims is to construct regionalized sustainability models to assist the research and policymaking processes related to Climate and Global Sustainability (Klimaat en Mondiale Duurzaamheid, KMD). This effort should use the existing models at MNP as a starting point, notably the population model PHOENIX, the energy model TIMER and the land-use, land-cover and emission/climate model IMAGE. The product should be a Global Integrated Sustainability Model or GISMO. This report presents the preliminary work that has been carried out in terms of context and outline for such a model of a major the world region: India. It is based on a small project conducted between September 2005 and June 2006 by Aromar Revi (TARU Delhi) and Bert de Vries (MNP) and on a 3-day workshop in Bilthoven in June 2006 with participants from the University of Colorado (Barry Hughes and Haider Khan), TARU (Aromar Revi, G K Bhat) and MNP (Henk Hilderink, Tom Kram, Ton Manders, Paul Lucas and Bert de Vries) (compare Appendix A). Both the project and the meeting were financed by MNP.

*Global Change models.* The objective of this report is to explore options and pitfalls in using Global Change models for an exploration of the future of the India region [1]. Since the construction of the first world model to explore the consequences of exponentially growing human populations and activities – the World3-model published in the Limits to Growth report to the Club of Rome (Meadows *et al.* 1972, 1991) – a suite of Global Change models have been constructed and used (see, for example, De Vries 2006). Several, such as the TARGETS-model (Rotmans and De Vries 1997), and the GUMBO-model (Boumans *et al.* 2002) resembled the World3-model in treating the world as a single aggregate system. Others focused instead on the regional dynamics and on the interactions of a region with the 'rest of the world'. Such a disaggregation was usually still rather crude, although the increasing availability of satellite data and Geographic Information System (GIS) software packages led to a rapid increase in spatial land-use land-cover descriptions and, in some places, land-use change processes. An example is the IMAGE-model (Alcamo *et al.* 1998; www.mnp.nl/image).

In terms of more complex developments, such as economic development, the dynamics of technological innovations and socio-political processes, formal modelling was understandably less advanced. One early attempt was the Globus-model, which attempted to capture the dynamics of political conflict (Bremer *et al.* 1987). This has been expanded in the subsequent years into the IFs-model (Hughes 2001; http://www.ifs.du.edu/). Another

[1] In the previous IMAGE-TIMER version, the region South-Asia includes India, Pakistan and Bangladesh. In the most recent version, India is desaggregated from South-Asia as one of the 27 regions considered.

direction was to develop national models in rather large detail, within a largely exogenous 'world development' context. A prime example is the Threshold-21 (T21) model collection (Barney/Millennium Institute; http://www.threshold21.com/).

*GISMO.* The MNP has adopted the strategy to develop a modelling integration tool called the GISMO-project with the aim of being able to address sustainability issues in a broad, integrated approach, with the durability and distribution of quality of life or human well-being as one of the major outcomes of sustainability. GISMO aims at:

1) *Integration* of the sustainability domains to gain insights in underlying *dynamics* of sustainable development make *interactions* between various domains visible (feedbacks, trade-offs between now and here to then and there, and co-benefits);

2) Positioning of, and integration with, the *institutional domain*;

3) Exploration of different *scenarios* and *policy interventions.*

As part of this endeavour, a workshop was organized at MNP in June 2006 with involvement of the MNP Global Change modellers (PHOENIX, IMAGE, TIMER), of the IFs team of the University of Colorado and of TARU New Delhi. Among the models used in this GISMO-project and discussed in this report are: the population and health model PHOENIX, the IFs Economy Module which uses (parts of) the IFs-model and the TIMER energy model, the land component of the IMAGE model and a water impact module.

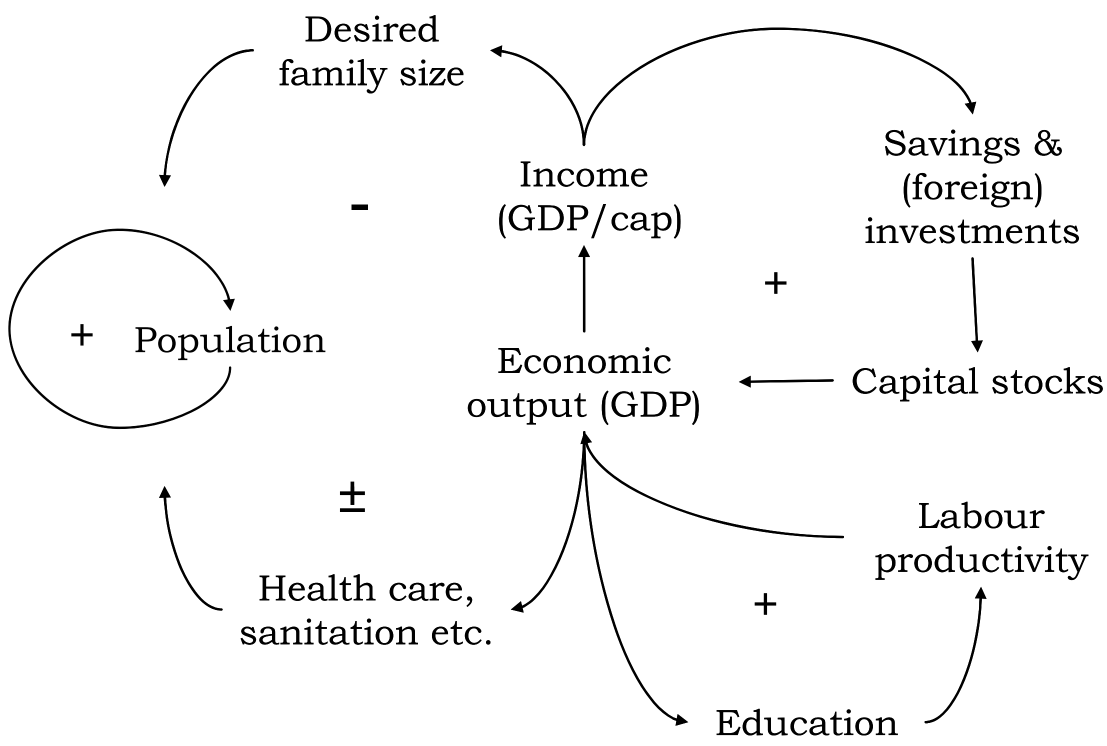
*Why India?* Desaggregation in global change models had a natural tendency to rely on the data, trends and mechanisms observed in the 'developed' countries of the Organization for Economic and Co-operation Development (OECD). Such an inherent globalizing-world bias led to the representation of less developed regions being as much a reflection – if not more so – of the OECD-societal values and institutions than those actually existing in the less developed regions. This was partly due to the overwhelming complexity of the increasingly interconnected world system, which often resulted in the easiest and most tractable approach being acceptance of the assumption that India, China and other large countries such as Brazil, Indonesia and Nigeria were all going to experience rapid economic growth – and in the process become more and more 'modern' in the Western sense of the word. The models were then used to assist multilateral institutions in issues of economic (under)development, trade and transboundary pollution. Indeed, these models do have generic modules (e.g. demographic, agriculture, international trade and finance) that have wider applicability than the context in which they were developed. Nevertheless, a large number of the central concerns of a developing nation (e.g. equity, employment, urbanization) undergoing a moderately fast economic transition and a slow but dramatic social transformation remain unaddressed [2].

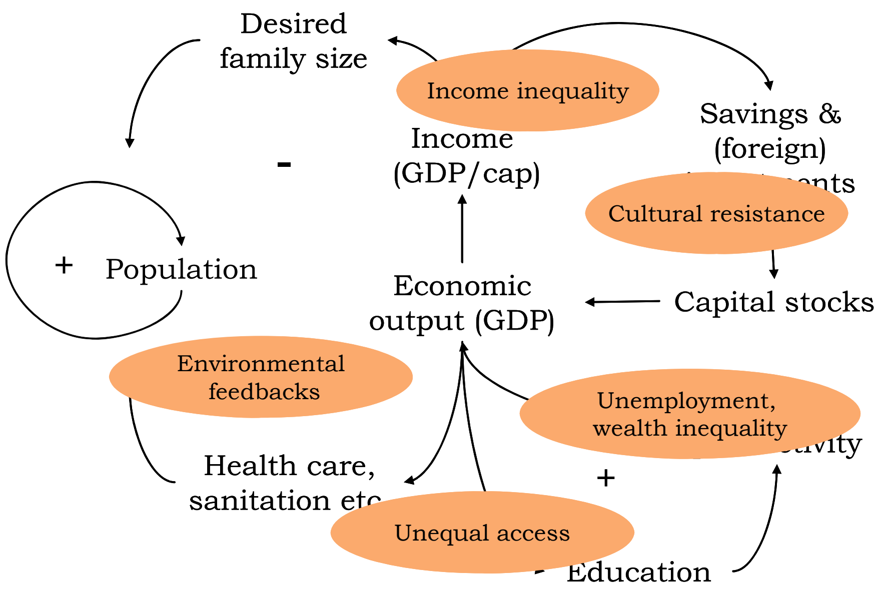
[2] This bias was quite obvious during the construction of the emission scenarios for the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (De Vries 2006; www.ipcc.ch).

Thus, although there is quite a large set of Global Change models available, they continue to have serious shortcomings, in particular for use in non-OECD-countries. The goal of the small-scale project, the outcome of which is presented here, is to:

- Explore some key trends, in some quantitative and qualitative detail, occurring in India over the past decades;
- Review a few dynamic national and global models and scenarios that have the potential to guide the development of a modelling framework:
  - for long-range planning for India as a complement to existing macro-economic approaches, and
  - for integration in KMD-MNP's Global Sustainability work in the form of a tested part of the GISMO;
- To undertake exploratory model simulations in order to determine the shortcomings in data and deficiencies in concepts, to trace potentially dangerous and risk-prone development paths and to confront outcomes with expert views.

To this end, we present a number of preliminary model simulations in order to determine shortcomings in data and deficiencies in concepts, to trace potentially dangerous and risk-prone development paths and to confront outcomes with expert views. The system dynamics diagrams presented below are a shorthand representation of our aim. The upper part of the graph indicates the mental map behind most of the desired and expected projections of (high) economic growth for India over the next decades. The lower part of the graph additionally shows the forces which may obstruct such growth in economic activity and/or reduce the improvements in the quality of life expected from it.






In more concrete terms, the focus in this report is on the following items:

- a qualitative analysis of the major socio-economic and political trends which have shaped India over the past 40 years (Chapter 2);
- a quantitative analysis of the major trends in the last 40 years in population, agriculture and economy and the derived inputs energy and water (Chapter 3);
- a brief overview of the projections of key variables in India's development over the next 20–100 years, based on MNP models and others (Chapter 4);
- an analysis of the projections of key variables for India in the 21st century with the Ifs-model (Chapter 5).

A series of Annexes presents more detailed information, on historical trends and forward projections for key variables, on input-output tables constructed for India for several years since 1978 and on some insights gained from discussions with experts.

# 2 India – trends and plans

## 2.1 India – an emerging force in the world

It should be a matter of considerable international concern that India – with the world's second largest population and fourth largest economy (in purchasing power parity (PPP) [3] terms), the largest concentration of poor people in history (over 270 million) and weaponised nuclear power – has no systematic analytical framework by which to explore long-range economic and resource management options. In spite of having a long history of economic planning and a large pool of talented economic and planning professionals, India's development focus is typically on the short-term (1–5 years) and at most on the medium-term (10–20 years) time horizon.

Given the dramatic demographic, economic, geo-political, resource and climate-related changes that are expected in the first half of the 21st century, the lack of a structured dialogue on key long-term challenges ranging from cross-border migration, fossil fuel scarcity and the potential conflicts between current and future Great Powers to the transition to renewables within India should be a matter of great concern.

This is not only a question of international development that should be relegated to the United Nations (UN), multinational finance institutions and OECD country development assistance and foreign affairs departments. India's future is a central question that will impact all peoples across the world because of its large future population (1.5 billion by 2050), large economic size (possibly the third largest economy in real terms by 2040) with a primarily poor population (per capita gross domestic product (GDP) in 2002 of 2,365 Indian Rupee (INR) of 1995), massive market size, severe resource constraints (land, water, liquid fossil fuels and biomass) and huge potential to contribute to greenhouse gas (GHG) emissions and transboundary pollution. With greater global interconnectedness and potentially greater insecurity, the future of the Indian people, its markets and its polity will become an important strategic concern for most OECD nations and, indeed, humankind.

## 2.2 Major long-range trends for 21st century India

A broad-brush look at India in the first half of the 21st century suggests the following, incomplete list of 18 trends:

1. Indian population grows from 1,000 million to over 1,500 million;
2. Ecosystem and land-cover changes take an ever larger share of Net Primary Production (NPP), with an increase in food production and urban land area;

[3] See Annex B for a list of acronyms.

3. Water-resource preemption and development for agricultural, industrial, energy and urban use;
4. Development of non-renewable (coal, oil, gas and nuclear) and renewable (biomass and wind) sources, technologies and infrastructure to meet increasing shortage in energy supply;
5. Slow urbanization led by large metropolitan growth with large informal settlements, poor infrastructure and declining living and working conditions;
6. Slow rural-agrarian transition to secondary and tertiary economic sectors, with the collapse of artisanal production, growth of non-farm rural livelihoods, informal urban services and public employment, 'jobless' growth and informalization in the industrial sector and rapid growth in organized services;
7. Expansion of the Indian 'state', with increasing democratic participation; political conflict between forward and backward castes, ethnic and linguistic groups for dominance, entitlements and patronage in the process of social and economic transformation;
8. Growth of the 'black economy', decay of public institutions, corruption and the massive increase in public programmes and spending in aid of special interest groups;
9. Increased life expectancy and slow growth in the quality of human development with the expansion of education, health and human services accompanied by a low growth in efficiency and a more informal and private provisioning of low quality despite large public investments and expenditure;
10. Development of new entrepreneurial institutions and classes in the private, cooperative and social/non-profit arena;
11. Slow decline in poverty, with increases in some regions; more rapid increases in differential wealth creation by new entrepreneurial classes, urban elites and entrenched dominant caste and trading groups;
12. Growth of knowledge-based services and industries and enclaves of excellence and globalization-linked wealth creation;
13. Growth and transformation of capital and commodity markets and formal financial systems and monetary and financial regulation, increasing penetration into the informal economy and inflow of international financial capital;
14. Development of strategic nuclear and missile capacity; ongoing low to medium-level conflicts along western and north-eastern borders; massive expansion of paramilitary and internal security forces with slow modernization of conventional military;
15. Increase in passenger and goods mobility and network coverage, with a shift towards road and personal vehicles and away from rail and water-borne transport accompanied by poor infrastructure quality, bottlenecks and high social costs;
16. Growth of religious intolerance, pockets of fundamentalism and new spiritual and social movements;
17. Increasing seasonal and permanent migration out of arid, semi-arid and strife torn regions to cities, and the emigration of skilled manpower to create a wealthy diaspora that has increasing influence on investment, entrepreneurship and politics;
18. The mobilization of lower-caste (Dalit) groups and of women in Indian society, with significant consequences for the social and political dynamics.

This list is neither complete nor unique. We do believe, however, that it covers most of the relevant items in the context of this report. In the next chapter, we discuss some subtrends and their proximate determinants over the 2$^{nd}$ half of the 20$^{th}$ century which are at the basis of this qualitative prospective (see also Annex C). The major data sources have been the TERI-TEDDY 2003-2004 dataset and the World Bank World Development Indicators 2004. The

TERI database also provides for each subsector a brief overview of major trends and prospects.

## 2.3 Medium-range planning in India: past and present

Medium-term (10–20 years) planning has been a feature of Indian national development processes since the 1930s with the creation of the Planning Committee of the Indian National Congress that was headed by Jawaharlal Nehru, later India's first Prime Minister. This created the core economic and developmental vision that underpinned the Constitutional settlement of 1947–1950. Running almost concurrently with this was the 'Bombay Plan', the vision of the national 'private sector' which – to the great surprise of many observers – maintained a very similar emphasis: a state-lead in economic development, public sector-led development of the core sector and moderate to high levels of regulation, among others.

Based on these 'vision' documents and the success of the Soviet Union's growth trajectory of the post-World War (WW)II era, India launched on its own a series of Five-Year Plans in the mid-1950s, with an emphasis on developing a planned mixed economy. A non-statutory body, the Planning Commission was created to lead and anchor this process in 1950, and the process itself was underpinned by the Mahanalobis-model (five-sector Input-Output (I-O)-model) that provided the growth and investment structure for the Second Plan (1957–1962). Under the influence of Mahanalobis and leading econometricians and operations research (OR) specialists of that era, subsequent Plans were based on an expanding the I-O-framework and eventually on Social Accounting Matrices (SAM) in order to estimate the economic and sectoral growth rates, sectoral investment shares and employment potential that would be generated. This was typically undertaken over a 5-year cycle with a mid-term appraisal of progress made under the Plan.

This process continued even after a period of liberalization (early 1990s), at which time the first- (1991–1996) and second-generation (2001–current) economic reforms occurred. The role and the centrality of the Planning Commission declined over the 1990s with the increasing influence of the Ministry of Finance on economic and development policy, the greater political decentralization of India's 28 states and the lower public financing of the Annual Development Plans. However, the planning process has been making a strong comeback since the late 1990s, with an increasing emphasis on decentralized planning in the 0.6 million villages, 5,500-odd urban settlements and 600-odd districts of India's 30 states. The Planning Commission's new role of investment mobilization for the national economy is also slowly developing with a more market-driven approach since 2004.

The medium-range (10–20 years) planning has been very broad-brush, through the vehicle of the Perspective Plan that typically provides context to each Five-Year Plan at the national level. Very few States have undertaken this exercise as they work within a fairly constrained economic envelope that is partially dictated by India's federal structure and resource transfers from the central government. Perspective Plans have typically been ‘vision’ documents that are not strictly linked to an economic model. The most recent effort was the development of a series of India 2020 visions, propelled by the work of the current President of India to make India a ‘developed nation by 2020’ (Planning Commission 2002). These exercises at both the national and state level are drawn from the strategic planning tradition more than strict economic or development planning. Typically produced by committees, they often contain contradictory omnibus statements of intent.

The Five-Year Plans continue to be analytically supported by three interrelated, but not necessarily integrated analytical processes:

- a population forecast based on a cohort population model;
- a national and sectoral econometric growth forecasting model;
- a national and sectoral investment estimation model (based on the growth model and derived via estimates of Incremental Capital Output Ratios (ICORs). This focuses on estimating public investment with private firm and household investments as the residual;
- a recent broad-brush econometric employment potential estimation model.

No attempt has been made to link these multiple analytical exercises into an integrated single or multilevel model that links population, resources and economic development. The closest attempts at integration have been the development of larger I-O-models to specifically examine the impact of energy policy and technical change in the 1980s. Some linkage to medium-scale Computable General Equilibrium (CGE) models have been developed by research institutions and academics.

With the decline in the importance of planning in the 1990s, few attempts at building independent national models for the Indian economy have been made publicly available. The most widely used are the CGE-models utilized by the World Bank (RMSM and its derivatives) and the International Monetary Fund (IMF) to develop their country growth forecasts and Country Development Plans [4]. The Energy and Resources Institute, formerly the Tata Energy Research Institute (TERI), has attempted to develop an India-centric long-range energy forecast, known as GREEN 2047 (TERI 2001), and independent academics have prepared independent medium-range forecasts. In keeping with the short-term view of much of the economic development currently taking place, especially in this post-liberalization era, the primary focus of economic, monetary and sectoral policy continues to be one of the short term.

[4] It should be noted that India has refused to participate in the World Bank Group-led Poverty Reduction Strategy Paper (PRSP) process..Nevertheless, the initial framework for the World Bank’s analysis of poverty has been strongly influenced by extensive Indian work on this question (Alhuwalia, et. al., 1979)

## 2.4 Rationale for an India 2050 model

It is a matter of concern that a country such as like India, which is so large in terms of people and economic activities, has hardly any integrative analytical framework with which to explore long-range economic and resource management opportunities and constraints in the context of the aspiration for a sustainable long-term development path. Given contemporary trends of increasing uncertainty, processes of moderate economic growth, technological and social transformation and massive population pressures combined with resource conflicts and weakening governance, an analytical framework could provide a common platform for dialogue on options – if it is constructed to respond to the more important contemporary policy and development questions and debates.

At the same time, it is essential for the work on global sustainability at MNP being carried out for, among others, the United Nations Environment Programme (UNEP) (GEO-IV) to work towards an integration of the existing, rather detailed land-use land-cover and climate model (IMAGE), population model (PHOENIX) and energy model (TIMER). If an adequate Regional Integrated Sustainability Model (RISMO) can be constructed for a region like India, it can serve as a template for the other regions in the IMAGE–PHOENIX–TIMER modelling framework. It can also be used to test the use of an overarching I-O-framework (as used in IFs and/or based on the Global Trade Analysis Project (GTAP) as a relatively simple and straightforward approach to evaluate sustainability goals – such as the Millennium Development Goals (MDGs) – with the capital, resource and other constraints.

This project is an initial first step to help define such a framework and to test it in a rudimentary manner against time-series data using a few broad-brush scenarios. Subsequent steps may include attempts at a more in-depth study of the approach along with the development of a two-level model (one for the Centre: All India, and one for the States) along with the integration of GIS-based geographically explicit models as well as attempts to link the approach with more detailed bottom-up resource, population and economic models that operate at the district and lower levels of aggregation. This would enable the linkage with geographically explicit global resource and economic development models.

# 3 India: important trends 1950–2000

In this chapter we briefly discuss some trends in population, land/food, economy and energy and water in the second part of the 20th century. The framework for this is the sectoral disaggregation as used in Global Change models such as TARGETS (Rotmans and De Vries 1997) and IFs (Hughes and Hillebrand 2006), which will be discussed in detail in a subsequent section.

One research problem is that comprehensive data are often available only at the aggregate All India level. At the more disaggregate level of states, districts and cities and towns, the available data appear to be rather patchy and awaiting analysis. This is understandable: at the more desaggregate level one has to incorporate the geographical, economic and socio-cultural heterogeneity which still exists in India and which may – for certain development pathways – be rather crucial. On the other hand, several projects – for instance, those on available biomass (compare Annex I) – are remarkable in their level of detail and width, so it may also be a matter of limited access and/or communication. In any event, serious forward projections for energy – but also for food and water – cannot rely on trend extrapolations for All India. They have to use the more desaggregate data and phenomena, if only because the opportunities and tensions emerging over the next decades will vary significantly. Although a significant body of data does exist, analysis of the long-term trends at the state level are rare.

In our analysis we find that a district-level description of demographic trends appears possible in terms of data. However, given the complexities of rural–urban migration, it is preferable to start at the state level. For economic activities, the situation is more difficult: even if state-level sectoral I-O-matrices become available, it will be hard to track the interactions with the increasing interstate fluxes of goods and people. In fact, it may be better to desaggregate in terms of characteristic economic zones. There are large and detailed data bases available for food that allow, in principle, a fairly rigorous analysis at the district level. The agro-ecological zone and soil maps can provide essential background features. The same holds for water, for which at least four subregions are to be distinguished. Here, the climate and precipitation data and the occurrences of ground water form necessary background data. The energy system has a natural scale element for sources such as hydropower, wind, biomass and solar-PV. However, an increasing part of the energy system consists of fossil fuels, for which transport is rather easy – here, the position of coal fields is an important element if only because of the large amounts of ash in Indian coal.

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*Scales.* The modelling framework to deal with (un)sustainable development issues, including climate change and development goals, covers various scales in space and time. Causes and consequences of global environmental change are, in these models, simulated in process chains, mostly in the form of material stocks and flows. In addition to data availability, the appropriate scale is also set by the nature of the processes and the objectives of the model experiments. Descriptions that are too fine-grained will have a huge data demand and possibly end in more, and not less, uncertainty. Descriptions that are too coarse-grained omit details which may be essential to understanding the nested dynamics involved or necessary to delivering meaningful policy messages.

A second aspect of the issue is the divide between the engineering 'bottom-up' approach and the (macro-) economic 'top-down' approach of modelling socio-ecological systems. This is partly a matter of conceptual simplification: the absence of humans in the engineering system and the extreme simplification of humans as economic-rational actors with perfect foresight in the economic system. Novel approaches in economic science, associated with the emerging branches of ecological and evolutionary economics, are advancing more realistic and heterogeneous descriptions of human behaviour. In the engineering sciences, there are continuing attempts to formulate a framework in which thermodynamic principles and units are merged with economic ones and in which material balance and process analyses are linked to economic I-O-frameworks and data.

## 3.1 Population

The Indian subcontinent has been for hundreds of years near its carrying capacity, in the sense that its population was so high that disturbances in the form of natural catastrophes or foreign invasions could easily lead to large-scale disruption. *Figure 1* indicates the frequency of famines in the regions of the Indian subcontinent (De Vries and Goudsblom 2002), which is one indicator of the rather precarious food situation in pre-Independence India. Whatever the causes were, the food situation has dramatically improved in the second half of the 20th century.

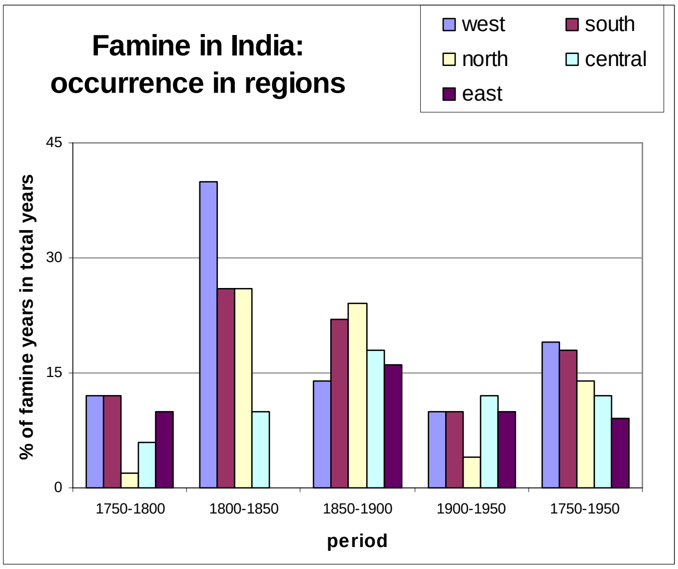



*Figure 1 Famine years in India in the past (De Vries and Goudsblom 2002)*

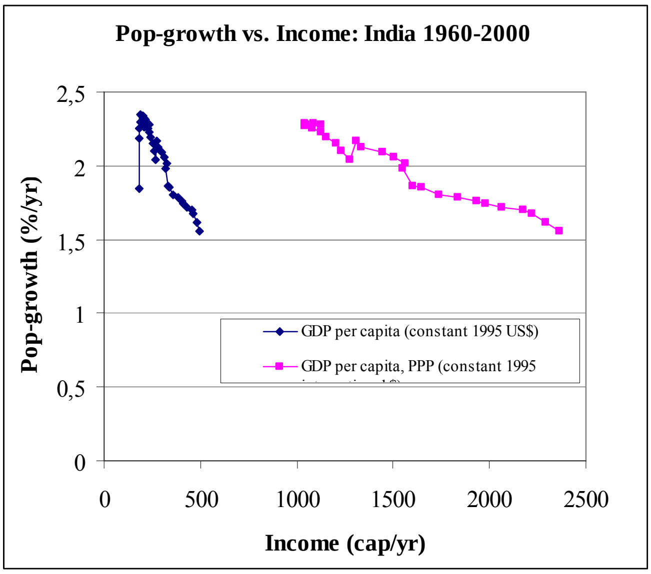



*Figure 2 Population growth rate versus income (with and without PPP correction) 1960–2000 (WDI).*

Since independence from British rule in 1947, India has undergone huge changes in population size, in the size and patterns of its economic activity, in its interactions with the rest of the world and in its regional and global use of resources and the environment. A first important point to note is that the Indian population has passed through the second stage of the *demographic transition*: its population increased between 1960 and 2000 from about 450 million to over 1 billion people. Death rates have steadily declined and seem to have stabilized somewhere between 8–9 per thousand. Life expectancy at birth has risen from 45 to 65 years. Birth rates have also declined, as shows up in the large decline in the fertility rate from over six live births per woman to about three. However, the difference between (average) death and birth rate is only slowly decreasing, and population growth is expected to continue for at least another 50 years.

The assumption of population growth rate being a parabolic function of income is not borne out by the trends since 1960. With the exception of 1960 and 1961, annual population growth has been declining with rising income (both in USD and INR) (*Figure 2*). However, the rise in income must be considered to be a major co-phenomenon that has permitted other important drivers to bring significant improvements in the food situation and medical and physical infrastructure since 1960, leading to (Annex C):

- a decline in child malnutrition, although it is still high;
- a gradual rise in the use of contraceptives and in birth attendance by skilled health staff;
- a significant increase in immunization programs and improvements in access to clean water sources, although a much slower access to sanitation;
- an increase in health expenditures as a fraction of income, showing up in the higher number of physicians and hospital beds per inhabitant, among others.

All these developments form part of what has been called the *health transition*, during which the emphasis shifts from environment-related causes of disease and death to more welfare-related causes (Niessen and Hilderink 1997). In the background, other developments have coincided and probably also been instrumental in this process, notably education. Spending on education has been on the rise, albeit with ups and downs, and the general level (literacy rate, school completion rate) of educations appears to be increasing as a long-term trend (Annex C).

An important aspect of population is its distribution, a first crude measure of which is often the *urbanization* rate. Although there are various definitions, the process of urbanization – that is, the more or less permanent migration of people to urban high-density areas – is occurring throughout the world – and India is no exception. The benefits of more income earning opportunities and better access to food and other amenities are, among others, major drivers. These may at some point no longer offset the disadvantages of living in ever more crowded urban metropolis. It is hard to say when this will happen, but there are signs that it may not be in the not-too-distant future in India. Perceptions and policies play an important but ambiguous role. During the past century the population density has increased throughout India, but this has not led to significant concentration at the state level (*Figure 3*).

Although numbers may be unreliable and give a distorted view of the reality behind it, it is clear that Indian society has experienced ‘modernization’ in a widespread and deeply significant way. For large and increasing important aspects of Indian society, it may also be argued that this success has led to such a population increase that Indian society at large is now in an equally or more precarious situation than in the past. This will be explored in subsequent chapters.

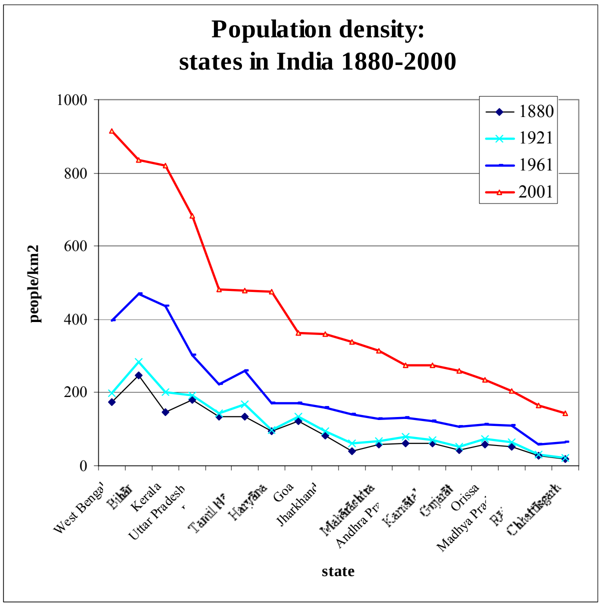



*Figure 3 Population density in Indian states for four years since 1880 (Klein Goldewijk 2005).*

## 3.2 Land/food [5]

Land and its characteristics are the first and foremost resource for human beings. According to official statistics, there has hardly been a change in land use in India since 1960 (Annex C). India's total land area is 300 million ha, of which about 23% is reported to be forest (including some cropping and grazing) and some 14% is reported to be unavailable for cultivation (urban areas, mountains, deserts…). The remaining area of about 195 million ha is largely used for agriculture – including land under fallow and tree crops. Pastures and other grazing lands comprise only about 10 million ha. Based on reports compiled over time, only the forested area has increased in size.

These statistics clearly indicate that India has only managed to feed its growing population by significant intensification. Since the 1960s the food situation has improved dramatically, commonly associated with the success of the *Green Revolution* in part of north-western India. Although the All-India results provide an inaccurate picture as they hide the disparities across the region, they still give an impression of the important transition which has been going on during the last four decades. Agricultural intensification has caused a 2.5-fold increase in crop production, with almost no extension in arable land – reflecting a large increase in crop yield. This was made possible by:

- the rapid increase in the use of yield-improving inputs, notably including – in addition to increased knowledge and skills – tractors (from almost none to some 2 million), fertilizers (from near-zero in 1960 to over 50 kg/ha in 1985 and to >90 kg/ha since then) and pesticides (from almost zero to over 0.4 kg/ha in 1988) [5];
- a concomitant rise in irrigated cropland from 15% to 30% of cropland (World Development Indicators (WDI) 2004) and in gross terms from 17% in 1951 to 39% in 2000 (IndiaStat);

[5] These high-yielding varieties (HYV) are varieties of seeds which have been developed scientifically with the help of plant breeding. Their area has increased from 9% of gross sown area in 1970 to 41% in 2000 – a remarkable increase indeed. As to the use of N+P+K fertilizers, IndiaStat gives a 240-fold increase of 0.7 mln tonnes in 1950 to 167 mln tonnes in 2000.

- a rise in multicropping: the ratio of total cropping area and net area sown has increased from 1.11 to 1.32.

As a consequence and in line with political objectives, there has been a decline in food imports: India is now largely self-sufficient in terms of providing food for its people. The environmental consequences of this intensification process are less clear, though some regions in Punjab and Haryana are reporting salinization and soil erosion. With the prospect of a steadily increasing population, the intensification has to continue – which makes the question of environmental sustainability as well as the success of new (bio-)technologies of great importance. Yet, there is room for choice and change. For example,, there is a tendency for fertilizer use to decline, and pesticide use has declined by over one third between 1988 and 2002.

In the post-independence period, agriculture and water management were characterized by several developments:

- Food shortages in the pre-1960 period led to large-scale investments in water resource development, specifically in the form of large- and medium-sized dams;
- During the 1950s and 1960s, key events were the construction of dams and the Green Revolution. The accent was on high-yielding varieties (HYV) with a neglect of millets and other semi-arid crops;
- Fom the 1970s onwards, the major developments were the expanding use of ground water and the availability of subsidized electricity at close to no cost;
- There was also an expansion and a shift to cash crops like sugarcane and cotton, driven by groundwater technologies;
- The 1990s saw growing differentials spatially and ground water droughts; around the year 2000 key issues were the reform of the electric power sector and the increasing distress of farmers in the semi-arid tropic (SAT) regions.

In terms of the growth potential of agriculture and, in particular, irrigated agriculture, it is to be noted that the potential for expansion of the net sown area (NSA) is very minimal and that the growth in gross sown area (GSA) is tenuous and very slow (1%/yr, with negative growth during drought years). Since the 1990s, the growth in gross irrigated area (GIA) has largely been driven by groundwater availability. There has been a decay of traditional water harvesting tanks (reduction from 4 to 3 Mha during the 1971–1991 period). Investments in surface water development since the 1990s have been low and the land area irrigated by canals is declining due to poor maintenance. Food grain yields and production have peaked in most regions in recent years.

What are the *constraints* for agricultural and irrigation development in India? There are a number of constraints related to the agro-ecological resource base, whereas others are interwoven with the institutions and policies which have shaped the present situation. Important constraints are:

- Complex terrain and resource constraints make decentralized planning an imperative;

- state boundaries are not compatible with natural resource zones;
- Government investments are drying up in irrigation – the poor returns are not even matching the running costs;
- The option of constructing large dams has mostly been exhausted, except in the high biodiversity and fragile Himalayan region, and interstate river basin conflicts are growing;
- In many areas there is a high population density and a high reliance on agriculture, with a shrinking land/person ratio;
- This, in turn, causes a set of related barriers to change, such as:
  - small holdings preventing growth and reinvestment in agriculture;
  - limited choices for water resource development;
  - optimal solutions at watershed/basin level are very difficult to negotiate between stakeholders;
- Co-existence of shifting agriculture, dry land farming and Green Revolution practices provides high diversity but also problems of interfacing with a market-based economy;
- A mentality of resignation among farmers due to prolonged poverty situations and natural calamities;
- High accessibility to information coupled with it low use has led to reactive solution;
- Soft state with long-delayed responses.

The economic importance of agriculture has steadily declined from almost 50% of the GDP in the 1960s to about 20% in 2000. Official employment in agriculture has declined from 70% in 1990 to 63% in 2002. It is typical for the structural change phenomenon: the growth is GDP stems largely from the rapidly growing industrial/manufacturing sector, although in India, the service sector also also contributed significantly, as will be discussed in the following section. A possibly important element in the future of agriculture is land-for-energy: large-scale energy plantations and other ways of using biomass to produce fuels or electricity are a promising avenue of income/resource.

## 3.3 Economy

Although India's economic development is taking shape within a very different context that is assumed by conventional macro-economic models used for OECD-country economies, these same models still provide a basic framework with which Indian economists also work. One such framework consists of a static description of the monetary transactions in the economy in the form of an I-O-matrix, an extension with details on the income distribution and final demand in the form of a Social Accounting Matrix (SAM) and a more or less detailed (neo-classical) economic growth model.

As part of this project, we have collected I-O-data on the Indian economy for the periods 1978–79, 1983–84, 1989–90, 1993–94 and 1998–99. Pradhan *et al*. (2006) provided extensive data on the SAM for India. The data presented in the following sections are based on the sources provided by these authors and the statistics from IndiaStat and the WDI (see Annex C).

*Income and expenditures.* Income per capita rose slowly from the 1950s to the mid-1980s: roughly a doubling in 40 years (compare Annex B). Some refer to the 'Hindu rate of growth'. Since the transition to a more market-oriented development in the early 1990s, economic growth has accelerated in certain sectors. However, per capita GDP is still at the low average level of 500 1995USD/cap/yr, and household expenditures are still less. However, expressed in international dollars – i.e. with a correction for PPP – income is considerably higher – more in the order of 2500 1995INR/cap/yr.

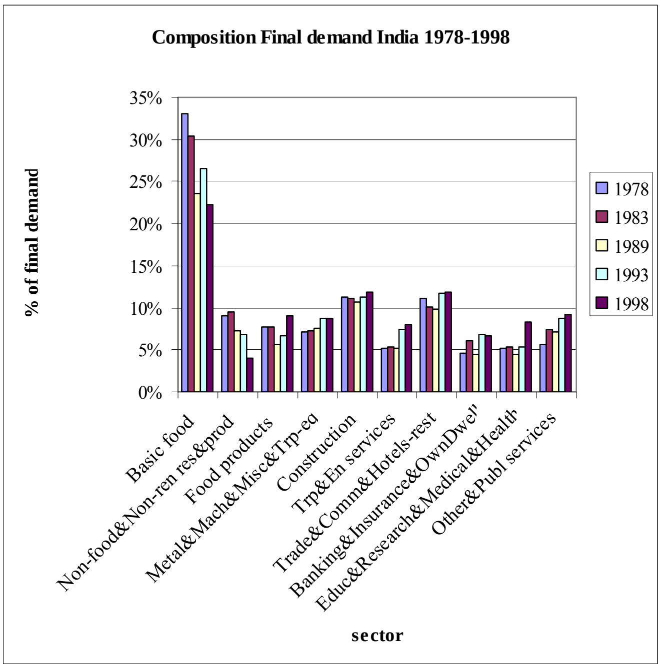



*Figure 4 Change in the composition of final demand in the official economy in India 1978–1998. The data sets are provisional; they still have to be checked for errors.*

The I-O-matrices give an impression of the structural change in the economy as reflected in the shift in final demand (*Figure 4*). Between 1978 and 1989, the fraction of expenditures on agricultural products in final demand declined from 40% to 30%, after which an increase occurred – more processed and quality food came in. Significant increases, up to 80%, occurred in this period in the fraction spent on transport and energy services and almost all services (e.g. financial, education and medical). However, one has to be careful with numbers. The National Accounts cover only part of economic activity: according to one estimate, non-taxed/registered Value-Added (VA) creating activities ('black' or clandestine labour) constituted 22.4% of the GDP as of 1989-90 (Schneider and Enste 2000). It is most likely that the size of the 'shadow economy' is much larger, certainly if we are to include all the non-market food transactions and 'illegal' transactions.

*Employment.* Agricultural employment was and still is dominant, declining from 70% of total employment in the 1970s to about 60% nowadays according to the official WDI (2004) statistics. Its slow decline coincides with an increase of employment in services. Employment in manufacturing and industrial production remained remarkably constant between 1990 and 1995 – the only data available. If India's service sector follows the trend of most other countries in terms of employment share, there will be a further gradual increase in the service sector employment share with rising income (*Figure 5*).

*Value-Added.* With respect to VA, the situation is quite different (*Figure 6*). Whereas in the 1960s and 1970s the contribution of agriculture was roughly constant at 45–50%, its share has declined steadily to less than 25% in 2000. Simultaneously, the VA generation in non-manufacturing industries and especially that in services has risen, from 6% and 34% to 11% and 51%, respectively. This suggests the importance of large-scale industry and information and communications technology (ICT)-based international services in the pattern of economic growth in India in the last few decades. The 'stylized fact' of structural change – a rising share of first industry/manufacturing and later services in GDP with income – apparently started in the early 1970s but did not continue.

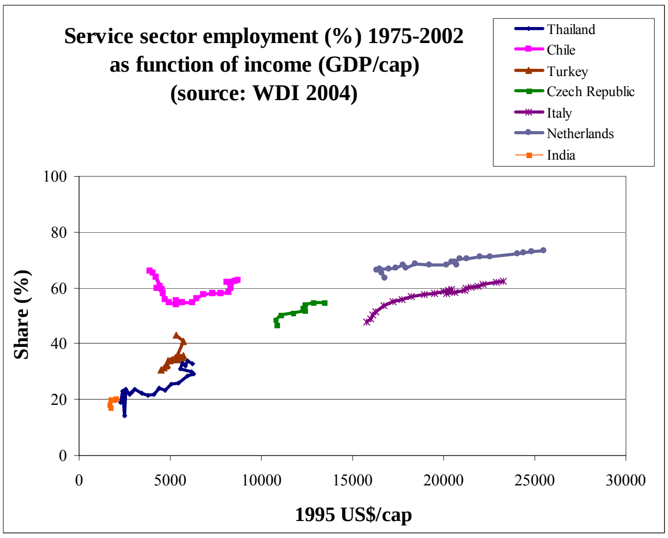
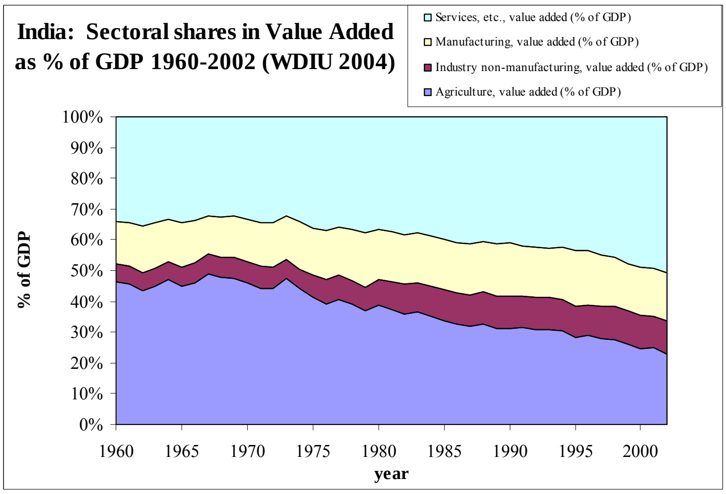



*Figure 5 Employment in the service sector as a fraction of total official employment versus income for India and six other countries (WDI).*

*Figure 6 Sectoral shares of Value-Added in India 1960–2003(WDI).*




*Income distribution and rural/urban – male/female distribution of employment and wages.* Data collected by Pradhan *et al.* (2006) provide the opportunity for a closer look into the nature of employment. In 1994–1995, 334 million people are list in the SAM as being formally employed; this represents about 36% of the population in that period [6]. Estimates on these people are available in terms of their background (urban/rural, male/female), educational level (six classes) and the economic sector in which they were employed.

Table 1 shows the distribution of all people employed and all illiterate people employed in India in 1994–1995 broken down into urban/rural and male/female categories across the three

[6] Using an urbanization rate of 26%, the fraction employed would be 31% for urban and 38% for rural regions. This may indicate an overestimation of the urbanization rate.

largest economic sectors: agriculture, industry and services. The numbers show that rural agriculture workers constitute the core of the illiterate workforce – one third of the total – and that male urban and rural service sector employees constitute the core of the educated workforce – one fifth of the total. There is a large and growing divide between the poor and illiterate on the one hand and the wealthy and educated on the other.

*Table 1 Statistics on employment (expressed in millions of people) in India in 1998–1999 (Pradhan et al. 2006).*

| **all employed** | urban male | urban female | rural male | rural female |
|---|---|---|---|---|
| agriculture | **4** | **2** | **124** | **70** |
| industry | **14** | **3** | **14** | **7** |
| services | **43** | **9** | **37** | **6** |
| | | | | |
| **illiterate (level 1) employed** | urban male | urban female | rural male | rural female |
| agriculture | **1** | **2** | **57** | **54** |
| industry | **2** | **1** | **4** | **4** |
| services | **6** | **3** | **9** | **3** |

The data indicate that (Table 1 and Annex C):

- of the 61 million males and 14 million female employed in urban areas, almost 50% worked in only two sectors, the wholesale, retail trade etc. and community, social, personal services etc.; this underscores the service character of the urban economy;
- education was highest among male workers in the finance, insurance, real estate etc. and community, social, personal services etc. sectors;
- the majority of the officially employed people in urban areas in agriculture, manufacturing and construction have a low educational level (less than secondary school); these ‘illiterate urban workers’ amount to 20 million people in total;
- of the 175 million males and 83 million females employed in rural areas, 62% (male) and 82% (female) have low levels of education (less than secondary school) and are working in agriculture.

It is often assumed that the income gradient between the urban and rural areas is the main driving force of the urbanization process. The estimates of the VA suggest a significant and rapidly growing wage differential between the agricultural sector, which dominates the rural areas, and the manufacturing and, even more, the service sector, which prevail in the urban areas. The data suggest between 1960 and 2002 a threefold and fourfold increase in VA per capita (USD 1995) in industry and services, respectively, against a 1.6-fold increase in agriculture (Annex C).

The SAM data (Pradhan *et al.* 2006) also provide information on the status of workers – self-employed, regular or casual – and average weekly earnings. The data suggest that in 1993–1994 almost two out of three workers in rural areas were self-employed, predominantly in agriculture, in comparison to 0.4 in urban areas, predominantly in wholesale and retail trade. These data also indicate a broad income disparity, ranging from a low of 73 for illiterate rural women in agriculture to a high of 1501 for well-educated urban males in the community, social, personal services sector.

*Economic structure.* The I-O-matrices provide, despite their probable errors and ambiguities, an indication of the structure of the Indian economy and the changes it has undergone during the last decades. An important cluster of the economy had to do with the land: food crops, cash crops, plantation and other crops, animal husbandry, forestry and logging and fishing. The composition of this cluster has not much changed since the 1970s, but its importance in the economy as a whole has declined. A second important cluster that increasingly dominates the formal economy, is manufacturing – with an important role for agro-processing – and services. Of particular importance here are trade and banking and other services. However, it remains difficult to interpret precisely just what is occurring in these sectors (see e.g. Dasgupta and Singh 2005).

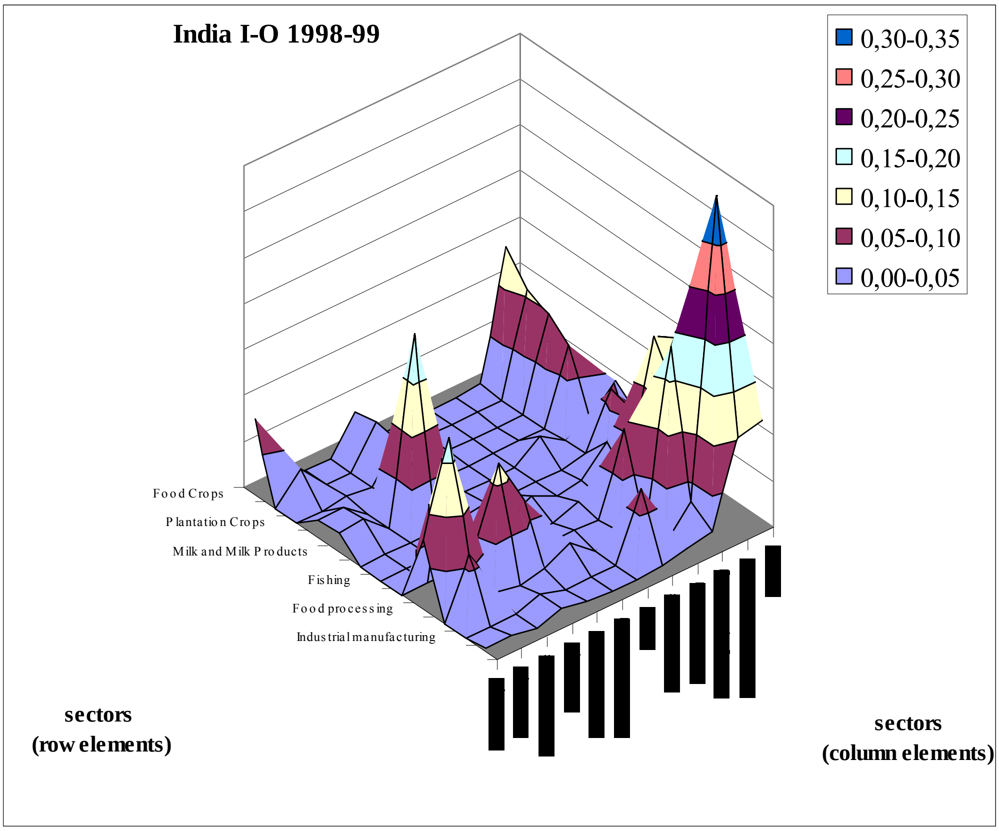



*Figure 7 The technical coefficients of the input-output (I-O) matrix for India 1998–1999. The height of cell (i,j) indicates the fraction of the total output of sector i (row)that is delivered to sector j (column). (Data source: Pradhan et al. 2006)*

Since the change to a more open economy, trade and in particular trade in other products than goods has increased significantly – from about 15% of the GDP in the 1980s to 30% around 2000 (Annex C). The monetary fluxes given as intra-India trade have grown enormously, which is a sign of an increasing specialization and differential growth in the economy. Broadly speaking, there are four regional dynamics which can be distinguished, although they are highly interrelated via population migration and other exchange processes. India's western seaboard from Gujarat and Maharashtra via Karnataka and Kerala is set to experience extensive growth as manufacturing and trade expand, and the Konkan railway, new ports and energy hubs provide opportunities for growth. Other smaller regions along the eastern coast, specifically eastern Tamil Nadu, the Krishna and Godavari delta regions and enclaves in coastal Orissa and West Bengal, will also integrate with the global economy along with service sector centres such as Bangalore and the region surrounding the National Capital Region of Delhi. Agro-based and mineral-based growth can be expected in north-western India, specifically Punjab, Haryana, western UP, parts of Rajasthan and Madhya Pradesh. Large industrial concentrations around energy and mineral resources in eastern India, specifically Jharkhand, Orissa, Chhattisgarh and Madhya Pradesh, can be expected. The rest of India, especially the villages of north, eastern and north-eastern India, will be significantly challenged to integrate into a rapidly changing economic landscape.

## 3.4 Derived demands: energy, transport and water

Any economic activity requires primary inputs: (skilled) labour, capital goods and the financial system to provide these, material process inputs (such as wood, stone and metals) and energy derived from renewable sources or fossil fuels. In addition, there is the need for land for agriculture and land for ecosystem services. All of these provisions require infrastructure investments for their growth and maintenance and represent some form of utilization – i.e. welfare extraction. This inevitably causes pressures on the natural resources base and the ecosystem services provided. Many of these are related to a few subsystems: food provision (including logging and fisheries), water and energy provision systems and the transport of goods and people. Food has been discussed; we now turn briefly to energy, transport and water.

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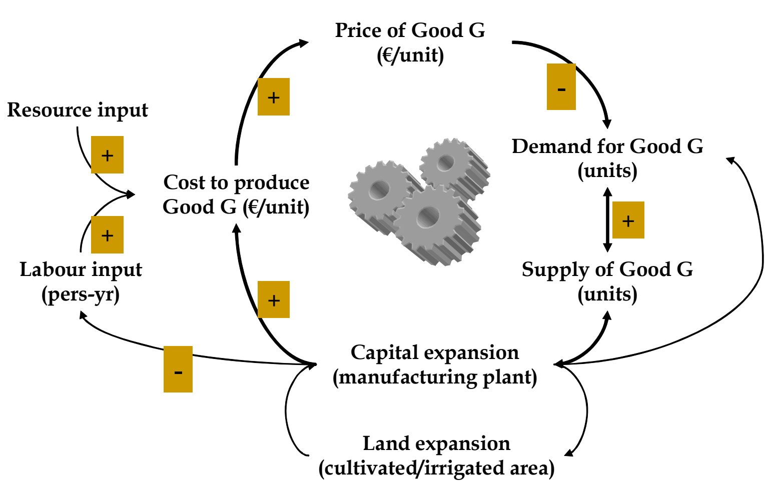
What is the dynamics behind energy and water use? Most economists (read economic models) treat energy as an exogenous input to a production process with capital and labour as the two key production factors. During the 1970s, with its two oil crises, both energy and materials were also considered as relevant inputs for production – the so-called KLEM production function approach. Water has hardly entered the formal analyses – 'its monetary value is so small that it can be neglected in macro-economic analyses', as a prominent economist once stated. Yet, this neoclassical economic approach has been increasingly criticized for its abstraction from the physical world with its laws of thermodynamics.

Evidently, economic growth depends on labour productivity growth, which can only be accomplished (in agriculture and manufacturing) by substituting commercial energy (fuels/electricity) for manual labour, with capital as a compliment (see e.g. Ayres 2003, 2005). It has been estimated that the persistent electricity shortage during certain periods of the year has caused India's GDP to be several percentage points

The demand-supply equilibrating loop



lower than were it to have an adequate supply. Secondly, energy is a crucial factor in the provision of services and in consumption activities via a large variety of 'energy services', such as the transport of goods and passengers, space cooling and heating, food preparation and preservation, communication, among others. In these situations energy is only partly a production factor *per se*: it allows people to do all kinds of activities, and without it a large part of economic life would come to a standstill.

To the best of our knowledge, a good conceptual model of economic growth which takes into account the combined role of technical change and resource use/degradation has not yet been developed for India. One growth dynamic is the loop shown in the scheme (De Vries 2006). With an increase in demand for a good or service, the input of capital – and land/space – will increase. The combined effect of economies of scale and innovations will lead to a downward pressure on the costs (read price of the good or service), even after rewarding capital (profits) and labour (wage rate increase). Demand will then tend to increase, with a further rise in the inputs of physical inputs: land/space, energy, water. As a result, it is hard to predict – with any reliability – the long-term trends in energy- and water-intensity, that is, the amount of energy and/or water used per unit of economic output (GDP) or VA. The tendency for energy is that energy use per person tends to stabilize and energy use per unit of GDP tends to decline. This is partly based on intersectoral shifts – from agriculture to manufacturing to services (see above) – and partly based on the fact that within each economic sector, the energy input per unit of VA will decline as the product incorporates more and higher-skilled labour and knowledge-incorporating capital goods which make up the larger part of the cost (read price). For water, such analyses are not yet available.

### 3.4.1 Energy

It has only been in the last few decades that energy use in India started to grow; prior to this time, it was more or less constant, with the larger part being provided in the form of traditional fuels (fuelwood, dung etc.) for residential use. In the 1970s All India energy use (in this case, Production) was roughly the same as that in the Netherlands around 1975. Although it is hard to obtrain reliable statistics, the following broad trends can be determined the period 1950–2000 (Annex C and e.g. Reddy and Balachandra 2000, 2005):

- Until the end of the 20$^{th}$ century, Indian society was still characterized by a large use of biomass-based energy sources and, to an increasing extent, indigenous coal;
- Although crude oil and natural gas deposits were discovered in the 1970s and exploited since that time, production has hardly expanded and does not exceed 1970s coal production levels;
- The exponentially rising energy demand has been met increasingly from two sources: coal and imported oil;
- Total energy imports – mostly crude oil – have increased to some 20% of commercial energy use, and this causes, with rising and fluctuating world market prices, fuel imports to be in the range of 20–30% of all merchandise imports;
- As in most countries, electricity use has been growing fastest; the share of hydropower in electricity generation has more than halved since 1970 (to about 8%), whereas the share of coal has gone up from 50% to 80%;

- Although the energy intensity (GJ/INR) has continued to decline, partly as a result of the rather strong growth of the service sector, the increase in energy demand is growing in pace with population and income growth.

A few graphs can illustrate these points. First, *agriculture*. As *Figure 8* shows, the 'Green Revolution' leap forward in food production has been made possible by an enormous increase in the use of agricultural machinery – tractors, oil engines, irrigation pumps – the operation of which which depends on diesel and electricity. It is one example of the development process in which labour is substituted by two complementary production factors: capital and energy. Both tend to be scarce in rural India, but their ratio will also reflect the relative cost (in this case, price) of capital and fuel/electricity, respectively. Such a development process starts in agriculture and necessarily involves a roughly proportional increase of energy per person with income.

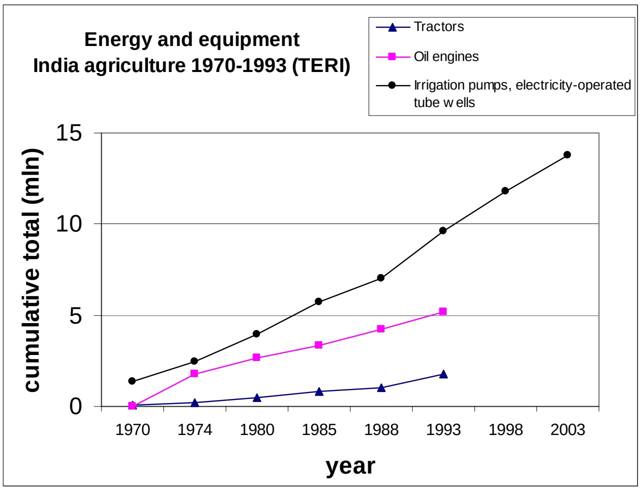



*Figure 8 Use of tractors, oil engines and irrigation pumps in India 1970–1993/2003 (Data source: TERI).*

Secondly, the *electricity sector* (see Annex C). As in most countries, growth in electricity use has exceeded GDP-growth. To satisfy this rapid demand, the system of State Electricity Boards and All India government organizations has responded with a rapid expansion in coal-based large-scale electric power generation plants. With liberalization, slow changes seem to be emerging in the operation and planning of the electricity system. However, important problems remain:

- Serious shortages in power supply in urban regions. Key states such as Gujarat, Uttar Pradesh, Madhya Pradesh and Maharashtra had peak power deficits in the range of 17–25% and annual energy deficits between 7% and 20% (Planning Commission 2005). The resulting low reliability has lead to investment in decentralized generation options which may well be suboptimal (IIR 2006). The brown- and black-outs resulting from electric power shortages also reduce manufacturing output – some analyses estimate a loss of 2–3% GDP;
- A still very low level of electricity service availability in rural areas, despite the large electrification programmes. The reason is not only the existence of tens of thousands of villages which are hard to reach, but also the low investments in village electrification in the villages formally connected to the grid. In addition, electricity in rural areas is heavily subsidized, hence costs are not recovered, and many electricity companies face severe debts.

Thirdly, *biomass-derived energy*. The so-called non-commercial traditional fuels constituted 34% of total energy use in India in 1996–1997. Even today in rural India, domestic energy use is dominated by fuelwood, crop residue and dung cake. Apart from local air pollution and resulting health impacts, these energy sources pose a serious threat to the forests. Of the 397 million cubic metres of fuelwood consumption in South Asia in 2000, 74% took place in India, which is roughly proportional to its population share. Using a Forest Service estimate of 21 million tonnes incremental growth in the forests, the current removal rate of 103 million tonnes per year is an indication of the large degree of overexploitation (Hooda and Rawat 2006) [7].

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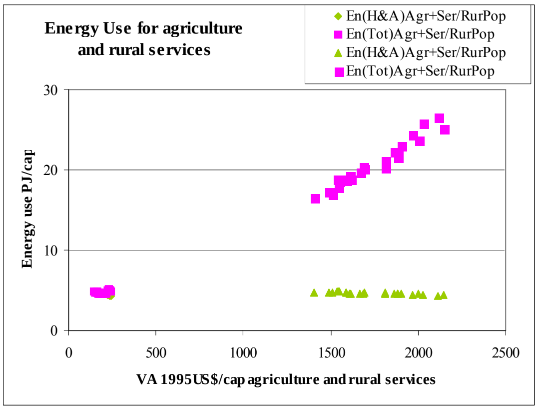
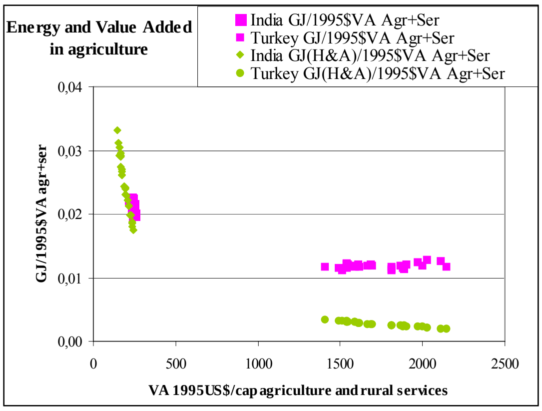
*The role of 'subsistence energy'.* At subsistence level the larger part of energy flows for humans are organic: food metabolism and livestock. With rising income, this 'subsistence energy flow' (human an animal, or H&A) remains roughly constant per person, as one would expect. However, the amount of non-organic energy increases roughly proportionately with the officially counted monetary VA per person in agricultural and rural services. With rising income, the energy-intensity measured as energy per unit VA declines, particularly for human and animal labour. These trends can be seen in the graphs below, for Turkey and India during the last two decades.




## 3.4.2 Transport

A similar link as in agriculture exists for *transport*, which is essential for the process of economic development and for which energy and notably oil products are essential. There has been a rise in transport services in India since 1975, with a steady rise in vehicle ownership – although the levels are still a small fraction of those in the OECD-countries (Annex C and e.g. Ramanathan and Parikh 1999). The process can be understood as one more transition along the path to modernization: from walking/bicycling to buses and scooters and, finally, to private cars. In large Indian cities, the share of buses in the total trips still exceeds the share of cars by a factor of ten on average (IIR 2006). However, it is uncertain how long this situation will remain given that the growth rate of vehicles has exceeded the population growth rate in large cities by a factor two (Kolkata) to seven (Chennai). Reliance on public transport and the use of non-motorized transport modes is declining in urban areas. There were 634,000 registered buses in 2001 in India; in the same year over 4 million cars were sold in India.

There has been a corresponding increase in the use of diesel and gasoline as well as in traffic accidents and air pollution and a rise in the construction of infrastructure (roads, airports,

[7] Not all of it is considered non-commercial.

harbours). However, the trends do not necessarily coincide and/or have the same underlying explanation(s) as similar developments in, Europe, for example, during the post-WWII decades. For example, if the data are correct, the large role of air transport in passenger transport is remarkable – a case of leapfrogging – and reflects the relative advantage of air travel if investments in and planning of rail and road infrastructure are lagging behind.

Indeed, the 'transport transition' in the presently developing countries may be different from that experienced in the OECD-regions, in particular in the densely populated parts of Asia. The underlying reasons for this are:

- *Space limitation/congestion:* in densely populated areas, the problems of road and parking space requirements are such that congestion may drive the system to a near standstill, as large cities like Bangkok and Bangalore are experiencing every day. One consequence is that the motorized two-wheeler and the motor-rickshaw maintain a comparative advantage in terms of flexibility, average speed and costs (see IIR 2006).
- *Need for rapid infrastructure expansion:* this may be resolved by large-scale motorway construction, as has been undertaken in many Asian megacities. However, income growth and the subsequent growth of private car ownership and use tend to quickly clog newly available roads. The resulting shortfall causes enormous congestion. Although this may be a temporary phenomenon, one may expect serious longer-term limitations from rising land and house prices and from quality-of-life expectations among the middle classes.
- *Undesirable side-effects*: the rapid switch to motorized two-wheelers and cars is causing an increasing toll in terms of traffic accidents and urban air pollution. Since 1981 the number of people killed in traffic accidents – mostly pedestrians and cyclists – increased from 28,400 to 81,000 per year (IIR 2006). Suspended particulate matter (PM) levels in the air in metropolitan levels are well above the air quality standards. Without doubt, as past developments in the OECD-regions testify, the middle- and higher-class citizens will start to resist such a decline in their quality-of-life.
- *Oil import dependence*: the rapid increase in motorized transport is the main cause of India's increasing use of oil products and hence of its rising oil imports bill. This will generate serious balance-of-payments problems if it continues at present growth rates.

### 3.4.3 Water [8]

India (over the period 2000–2050) will be confronted with one of the most challenging resource use and management situations in the world. The availability of land, water and food are expected to show significant divergent trends between regions, with highly uneven ecological and resource endowments, access to land, increasing population pressure. Land and water resources are already subject to severe conflicts that range from the village to river-basin level. Even minor changes in resource endowments could severely impact and heighten human-biosphere conflicts. For this reason, forward projections of land, water and food developments – and also energy developments insofar as these rely on local resources – have

[8] This section is largely based upon the presentation *Food situation and water resource scenarios for India* by G.K. Bhat during the 19th Annual Balaton Group meeting in Hungary, September 2000, and an updated presentation during the MNP-workshop in June 2006.

to be made on the basis of explicit geographical information. Aggregate scenario building at the All India level is inadequate to explore future trajectories and options here.

From a water perspective, India should be subdivided into at least four distinct sub-regions: irrigated India, rainfed semi-arid India, mountainous India and underdeveloped India. Each is distinct in terms of population densities, resource endowment and use trends:

- *Irrigated India* has been able to achieve fairly high yields, but poor water management has resulted in water-logging and salination in large areas. This trend could result in productivity plateauing which, in turn, could affect the food security of large populations. Irrigation systems based on a snow-fed Indo-Gangetic plain river are most vulnerable to global climate change, especially since much of its potential is already tapped. Any reduction in trans-boundary flows could increase water conflicts with neighbouring Bangladesh and possibly Pakistan.
- *Semi-arid India* largely relies on the rainfed agriculture. Any change in the rainfall pattern or more significant rainfall variability could seriously affect these sub-regions. Pockets of intensive ground water-based agriculture are already suffering from drought as a result of over-extraction; out-migration, especially in drought years, is endemic.
- *Mountainous India* largely relies on subsistence cropping, with most agriculture being rainfed. This region is already food-deficient. The survival of these communities will depend on food imports from surplus regions, silvi/horticulture and the export of migrant labour.
- *Underdeveloped India* has been unable to reap the benefits of modern agriculture or irrigation technologies with large populations of indigenous and disenfranchised communities. Livelihoods are dependent on a mixed portfolio, ranging from non-timber forest produce to primitive agriculture. Deforestation, soil erosion and displacement by outsiders are serious concerns in some subregions (Kumar 2003)..

One serious issue is ground water depletion. The present situation is indicating a rather precarious balance in use and availability of ground water, as the projection for 2000 in the map shows (using the district as the unit of analysis and 1995 as the reference year) (*Figure 9*).

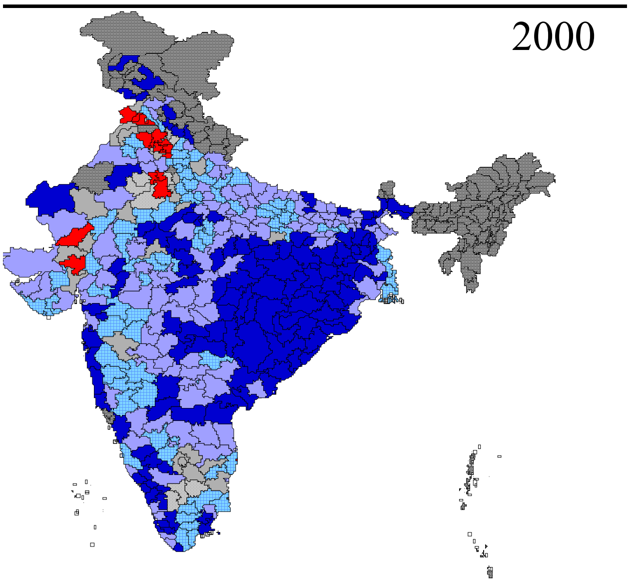



*Figure 9 Map indicating the ratio of groundwater use over renewable groundwater resources. (Data source: Central Ground water Board, Ministry of Water Resources, Ground water Statistics 1995)*

# 4 India 2020-2050: forward projections

## 4.1 General considerations

The trends discussed in the previous chapter are the basis for any forward-looking, long-term projection. However, many uncertainties still exist in terms of how these trends will or will not continue and whether they will really be the decisive in affecting the socio-ecological development of India. Almost certainly, important aspects of the complex dynamics of a large socio-ecological system such as that of the Indian subcontinent, which is becoming an increasingly important part of the global system, will be overlooked. Hence, the method of scenario analysis is often employed.

In essence, the scenario method combines the telling of consistent and, at least for the maker, possible or even plausible stories with more or less rigorous modelling. An interesting and useful framework is provided by the Special Report on Emissions Scenarios (SRES) for the IPCC (Nakicenovic *et al.* 2000; De Vries 2006). This framework distinguishes two major axes which can facilitate any analysis of possible future directions of the world: market-oriented and materialist versus government-oriented and immaterialist as one axis, and global orientation versus local orientation. Such a 'flattening' of the world is most certainly a huge simplification, but it nevertheless serves to organize some of the possible storylines for the future.

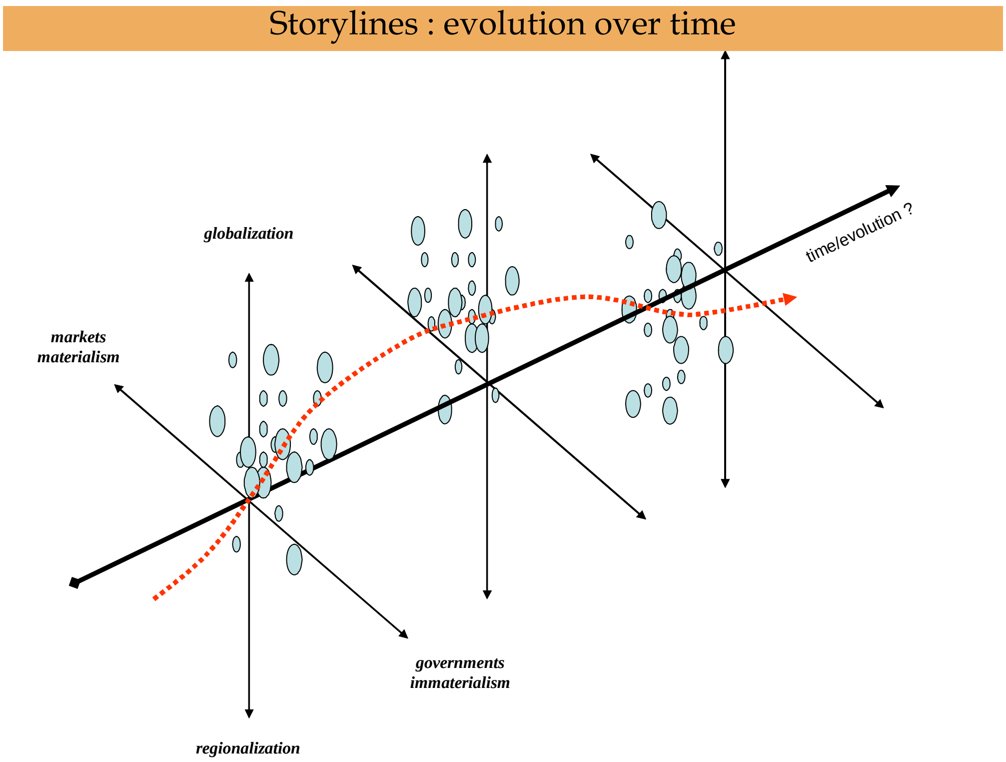



*Figure 10 Schematic representation of societal development as a process of the changing value patterns that drive important parts of the social-ecological dynamics.*

Because people's values and value-based interpretations of events are important driving forces in societal dynamics, it is possible to associate trends in certain directions – say, towards one of the corners of the plane – with underlying values (RIVM 2004). As indicated in *Figure 10*, a change in values and value-based interpretations over time may lead to a shift in the emphasis of how countries and regions should and will develop. For example, one can interpret the switch from the UN report 'Our Common Future' (upper right corner) towards the Global Market 1990s (upper left corner) to the cultural clashes of the beginning of the 21st century (lower left corner) in this framework. In the present context, it may serve as the framework to explore future developments in India.

## 4.2 Scenarios on population, food, water and energy

### 4.2.1 Population: PHOENIX-model simulations

*The PHOENIX-model.* The population and health model PHOENIX has been developed over the past 15 years, initially as part of the TARGETS-model (Rotmans and De Vries 1997). It describes the population dynamics for the world as a whole and has been extended and refined in latter versions with more regions and more detailed age groups and applied to various scales such as the world regions, 40 European countries, the Netherlands, India, China and Mexico (Hilderink 2000a, b; available at: http://www.mnp.nl/phoenix/Backgroundinfo/references/). PHOENIX is used to explore, develop and analyse different demographic scenarios at various geographical aggregation levels (i.e. regional, national and grid cell). This consistent approach to dealing with various scales makes it perfectly suitable to be used within integrated modelling frameworks, such as the IMAGE-framework (MNP 2006).

The demographic core of PHOENIX is formed by a cohort-component model consisting of 28 major world regions, 100 one-year age groups and the two sexes (*Figure 11a).* The main outcomes of this demographic core are population by size and sex and age structure. The inflow for the population (i.e. number of births by sex) is determined by a fertility submodel, while the outflow (i.e. deaths by gender and age) is determined by a health submodel. Migration is taken exogenously.

*Fertility model.* The fertility model outcome is the number of births by describing age-specific fertility rates, which are the result of a process of diffusion of innovation, a concept comparable to Easterlin's modernization (Easterlin 1983) and modelled through the level of development expressed by the Human Development Index (HDI; UNDP, 2005). The HDI determines a desired or wanted level of the total fertility rate (TFR), a level which is obtained through the diffusion process given a transition rate and the year of offset of the transition. The desired total fertility rate is, for some regions, adjusted for the preference for a son. The son preference effect has already been taken into account in the India application (Hutter *et* *al.* 1996, Hilderink 2000b). On a highly aggregated global level, this effect is rather small but it can have an effect that is not negligible in countries such as India, Pakistan, Bangladesh, China and South Korea. In addition, this effect becomes more evident with a rise in contraceptive prevalence and a decline in fertility level (Nag 1991). The consequences of the son preference are also revealed in the sex ratio at birth (SRB). Due to prenatal sex selection there are more than 100 million girls missing from the world (Sheth 2006). In most countries, the SRB is about 105 boys per 100 girls; the 2001 data available for India is not spectacularly different –108 boys per 100 girls. However, great variations exist between states: Punjab, Haryana, Delhi and Gujarat have a SRB between 114 and 126 boys per 100 girls (Sen 2003), taking birth order into account; in Delhi, the SRB for second order births is 138 and for third order even 247 boys per 100 girls (Varghese *et al.* 2005).

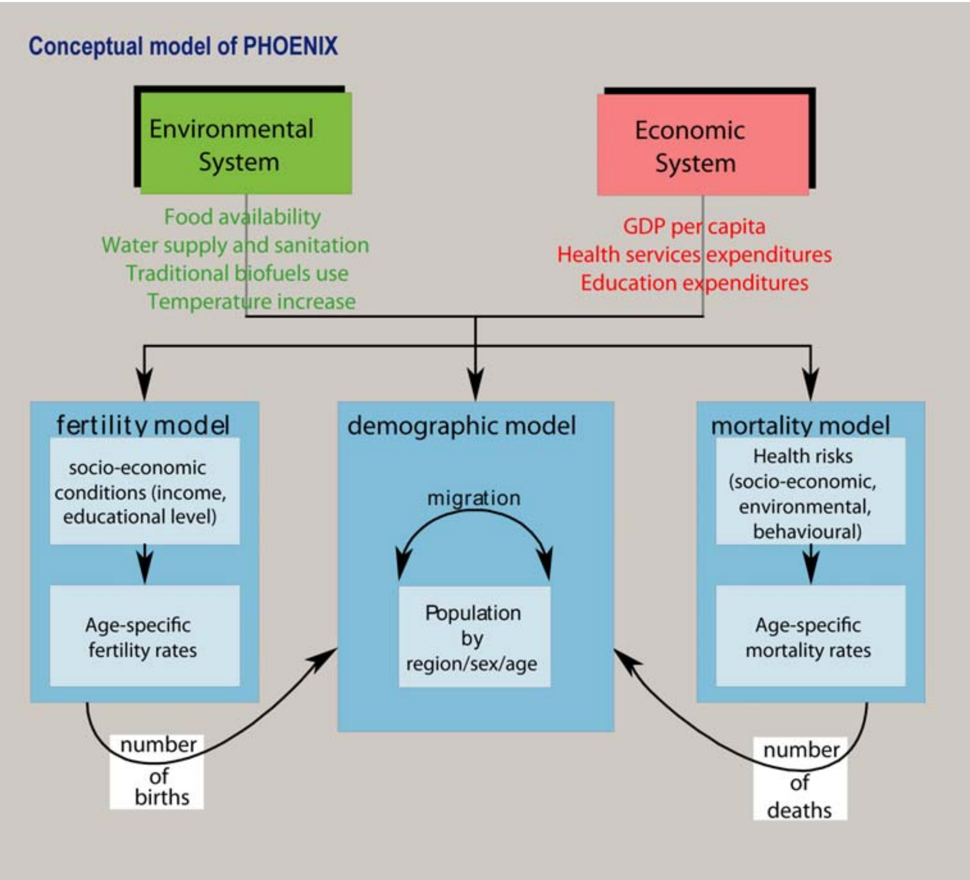
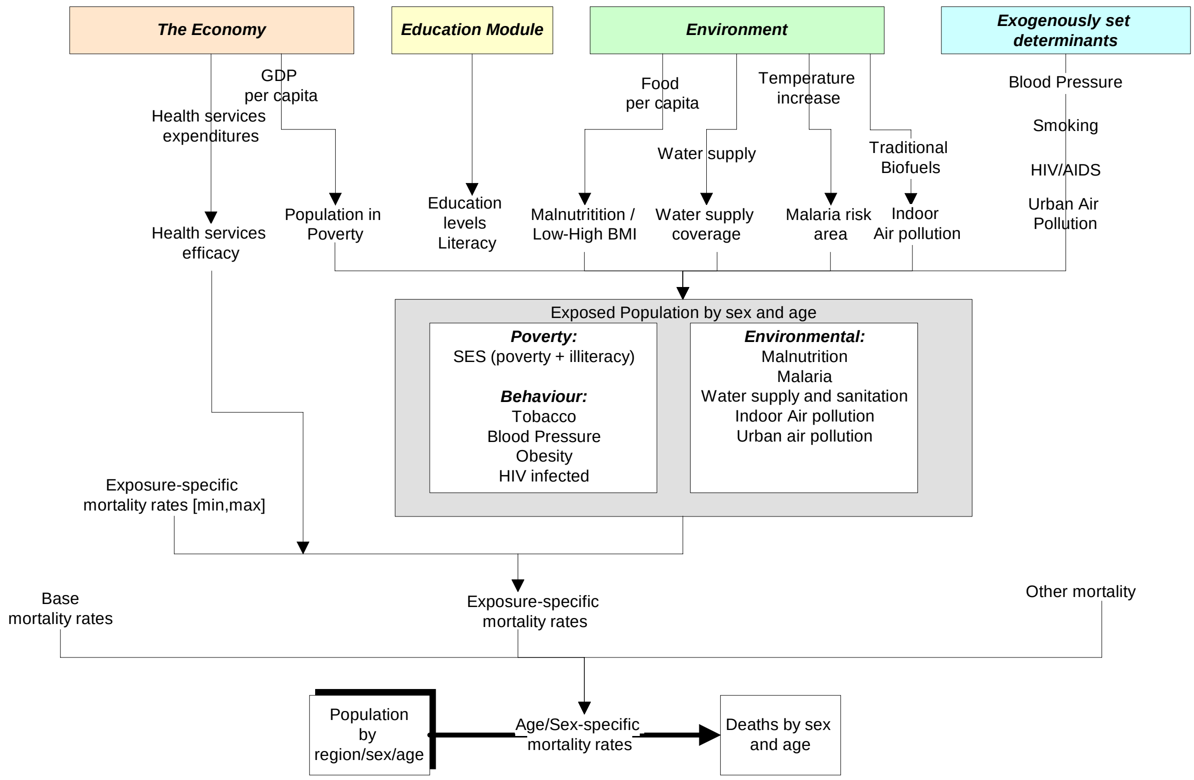



*Figure 11a Conceptual scheme of the PHOENIX-model*

*Mortality model.* The outflow from the mortality model is the age- and gender-specific number of deaths based on a selection of health risks. The mortality model in the PHOENIX approach has a strong connection with World Health Organization (WHO) data on health risk factors and outcomes (WHO 2000). Describing morbidity levels seems to be a bridge too far, at least at this stage, although the Global Burden of Diseases (GBD) provides some leads to take this into account for future steps. The sex- and age-specific mortality rates consist of three components: a base mortality component, an exposure-specific component and a category ‘other mortality’. All of these components are dealt with in an additive manner.

*Figure 11b The PHOENIX-model with the context, position and the interrelationships.*




The base or minimum mortality level is obtained if all health risks are eliminated and if all health services function at a maximum; such conditions correspond with a situation in which there are no premature deaths. This level determines the upper limit of life expectancy a population can reach. Estimations of this upper limit of life range from 80 to 120 years (Olshansky *et al.* 1990; Olshansky and Carnes 1997; Oeppen and Vaupel, 2002). The upper limit of life expectancy may even be prolonged up to 125 years with improved knowledge and medical technology (Tabeau 1997). However, these levels of life expectancies require changes in health practices and mortality schedules that appear to be inconsistent with what is practically achievable (Olshansky and Carnes 1996). On the suggestion of Fries (1980), a life expectancy of 85 years for males and 86 years for females will be taken as a starting point for the upper limit of longevity.

The dynamic and integrated character of the mortality module is represented by the exposure-specific mortality. This component is strongly interwoven with the socio-economic and environmental domain. It is modelled based on a multi-state approach distinguishing exposure and death. Special attention is given to health services that modify the transition rates between the various states. The most important socio-economic (socio-economic status (SES), comprising poverty and illiteracy), environmental (malnutrition, malaria, in- and outdoor air pollution, lack of safe drinking water and sanitation) and behavioural risks (tobacco, blood pressure, obesity, HIV-AIDS) make up an age- and gender-specific mortality rate. The level of health services determines to what extent a health risk contributes to these mortality rates. The ‘other mortality’ component is used as a calibration factor in order to reproduce historical mortality rates.

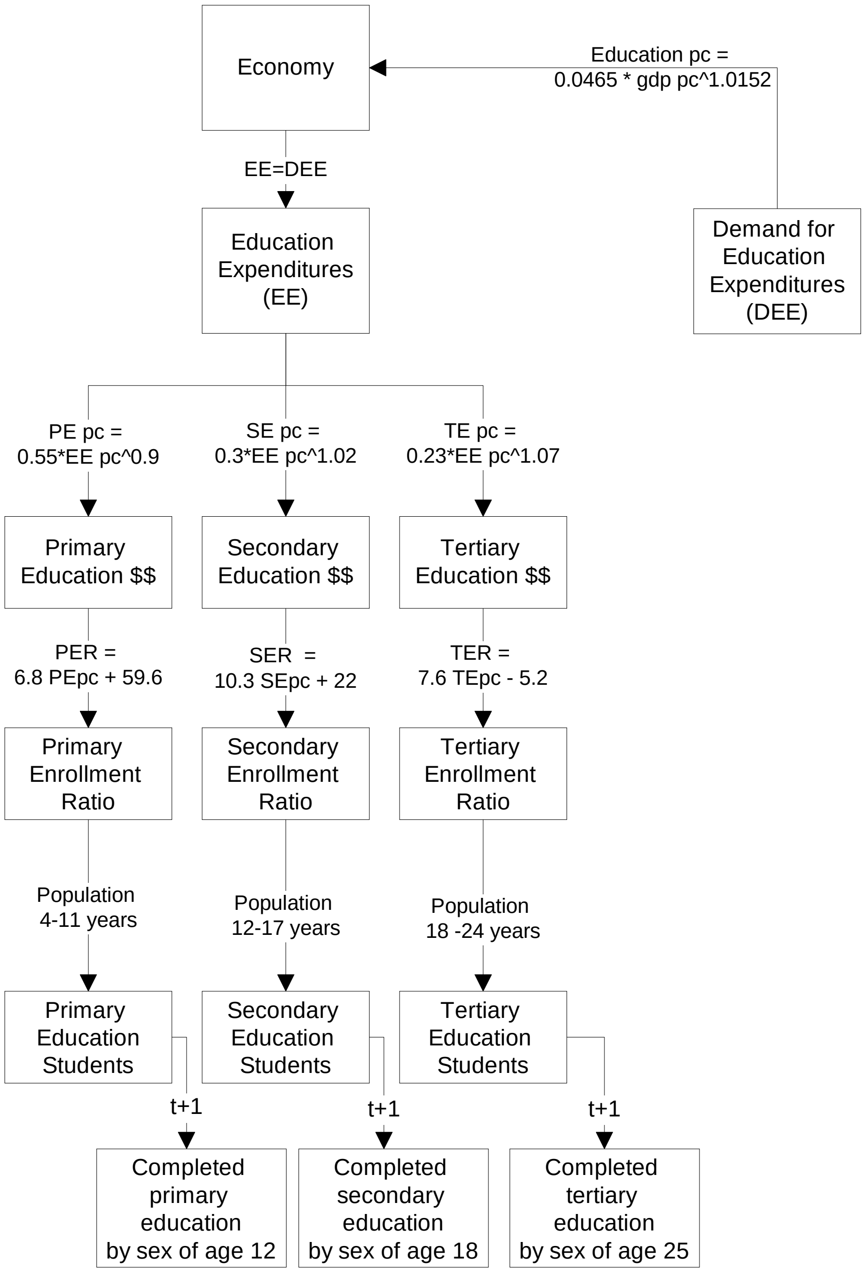



*Figure 11c The PHOENIX Education implementation.*

*Education module.* The intertwinement of aspects of education with both fertility through the HDI and mortality through socio-economic status already emphasizes its importance. On the other hand, education is also important for the integration of population with economic aspects through labour force and productivity. To describe these various facets of education dynamics, the PHOENIX-model has been extended with an education module, and in this form it serves rather well as an integrative platform for education modelling since it facilitates detailed modelling by distinguishing 100 age groups and the two sexes.

Education is described by a regression type of model in which four levels of education are considered (no education, primary, secondary and tertiary). The enrolment ratios are the combination of intake or entrance rates and the drop-out rates. In a first step, enrolment ratios are used as an input for the education module due to limited data availability on (historical) intake and drop-out rates. It is important to take these rates into account in the next phase as well so as, for example, to be able to calculate the average years of schooling. The start and end age of each level of education varies greatly among countries but is assumed here to be equal for all regions. Primary education is assumed to be from 5 up to 11 years of age, secondary from 12 up to 17 years and tertiary from 18 up to 24 years. Repeaters are not taken into account. The enrolment rates are gender-specific.

The equations for this model are given in *Figure 11c*; their derivation can be found in Hilderink (2007). The simulation period is 1950–2050. The first 50 years are used for calibration and validation purposes. This requires some additional data which are estimated based on the existing time series. The initialization of the model deserves more attention; however, no reliable data are available, and the calibration procedure revealed some deviations which need further investigation.

*Results and projections.* Some preliminary model results for India (South Asia) are given here in the form of graphs and tables (see also Annex D). The results presented here are the implementation of the OECD-reference scenario that is used for the OECD Environmental Outlook. The Indian population is expected to grow to 1.6 billion people by 2050 (*Figure 12*). This forward calculation agrees quite well with the official population forecasts of the Planning Commission for 2020 (*Table 2*; 2002, 2005) – not surprisingly as population growth follows a rather rigid dynamics barring unforeseen catastrophes. Yet, it may be on the high side if rapid economic growth and associated 'modernization' processes speed up the epidemiological transition (compare with Section 4.2.2). An enormous population momentum is building up over the next few decades, as *Figure 13* indicates. Such a population momentum will also have economic and political ramifications. Behind these dynamics is the demographic (or broader: epidemiological) transition, with a fall in fertility rate and mortality rate. The latter stems from a decline in the exposure to important poverty-related health risk factors, such as malnutrition, bad sanitation and diseases like malaria, in combination with an increase in the health service efficiency. After 2030, this decline is reversed due to the increase in base mortality from ageing.

India's favourable age structure, with a relatively high proportion of the population in the potentially economic active population of age 15–65 years, leads to the so-called demographic window of opportunity and may stimulate a rather high GDP growth rate. The GDP growth scenario is based on the assumption that the average labour productivity growth will converge to 1.78%/yr. This assumption influences the population growth path directly, via fertility and mortality, and indirectly, via health and education expenditures.

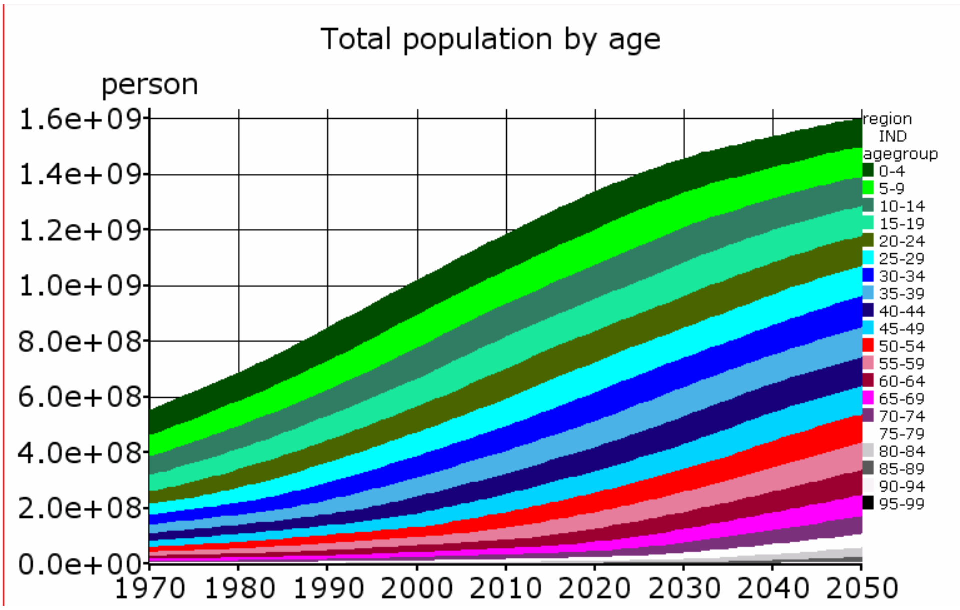



*Figure 12 The population size and age cohorts in India, as simulated with the PHOENIX-model.*

**Table 2: Population Projections (millions)**

| Year | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| Total | 1010 | 1093 | 1175 | 1256 | 1331 |
| Under 15 | 361 | 368 | 370 | 372 | 373 |
| 15-64 | 604 | 673 | 747 | 819 | 882 |
| 65+ | 45 | 51 | 58 | 65 | 76 |

Source: Based on P.N. Mari Bhatt, "Indian Demographic Scenario 2025", Institute of Economic Growth, New Delhi, Discussion Paper No. 27/2001.

*Table 2 Population projection for India until 2020 (Planning Commission 2002).*

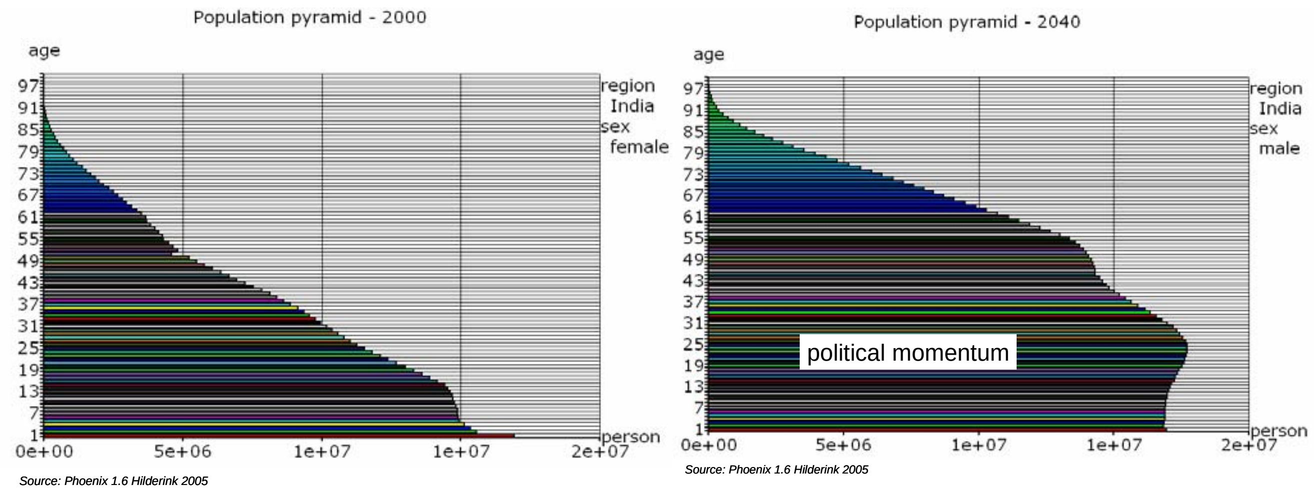



*Figure 13 Age groups of the female Indian population in 2000 (left) and the projected male Indian population in 2040 (right). The population momentum shown in the right-hand graph also represents an economic and political momentum.*

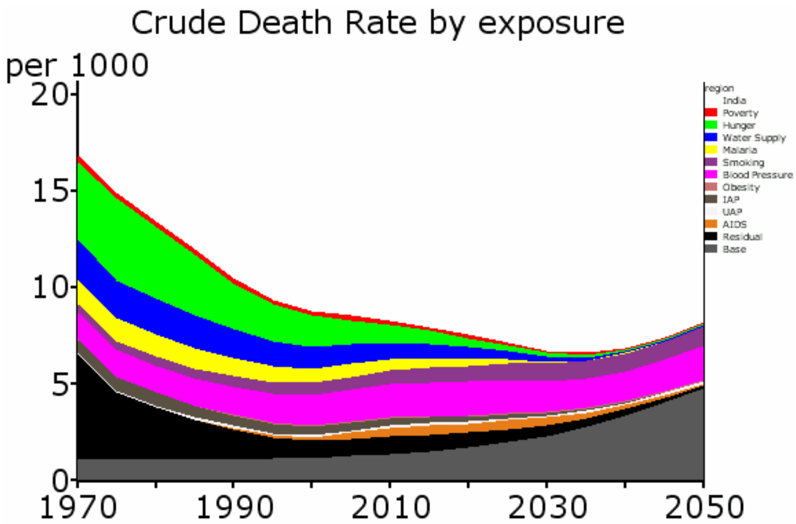



*Figure 14 Change in the average crude death rate in India 2000–2050, with base and residual mortality (lowest two), mortality due to seven diseases and mortality associated with inadequate water sanitation, under nutrition and poverty.*

The demographic developments in this scenario are in line with the UN-Medium variant of the World Population Prospects. The changes in age structure are the result of further declining fertility rates, reaching below-replacement fertility within 20 years. At the same time, the epidemiological transition will continue, and traditional health risks such as hunger, water and malaria will be pushed back further, making room for chronic diseases related to health risks as smoking and overweight (*Figure 14*). In 2050, the average life expectancy will be just below 80 years. At this time, the Indian population will be almost 1.6 billion persons, but the growth of the population is rapidly decreasing. The link between the epidemiological transition and the necessary rate and nature of economic growth is a topic to be analysed in more detail. Preliminary calculations indicate that as the demand for *health services* will increase, especially with an ageing population, the 3% of the GDP spent in 2000 on health services will increase to 5% by 2050.

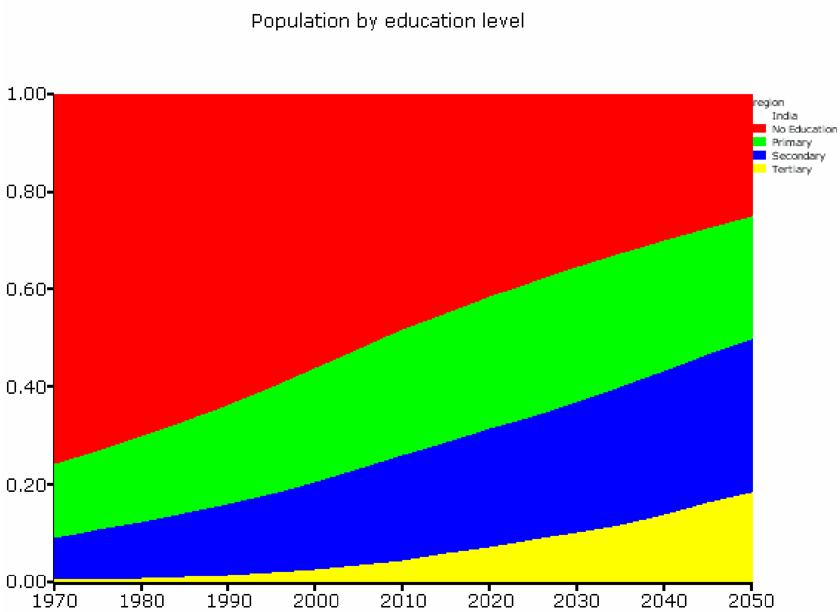



*Figure 15 Change in the education level of the Indian population 2000–2050, with four education levels.*

*Education expenditures* are the linchpin between the 'educational transition' on the one hand and rate and nature of economic growth on the other. Preliminary calculations suggest a similar increase as for health expenditures, at least over the first decades. These will subsequently – as a percentage of GDP – level off. This development is partly caused by the ‘degreening’ of the population: there are relatively fewer young people who have to go to school. In terms of educational developments, the consequences of increased enrolment ratios are clearly visible in educational attainment levels (*Figure 15*; Annex D). However, the simulation results also indicate that it takes more than 50 years to educate the whole population.

### 4.2.2 The economy: production and consumption

*The IFs-economy model.* The economy module developed in the GISMO-project is based on the economy module of the IFs-model (Hughes 2001; Hughes and Hillerand 2006), which is also referred to as Ifs-economy. IFs is a multi-regional model and constructed as a tool for thinking about long-term global futures. It includes several sub-modules such as technology, environmental resources, population, economy (especially agriculture and energy) and political modules, all of which are fully integrated with each other (*Figure 16*).

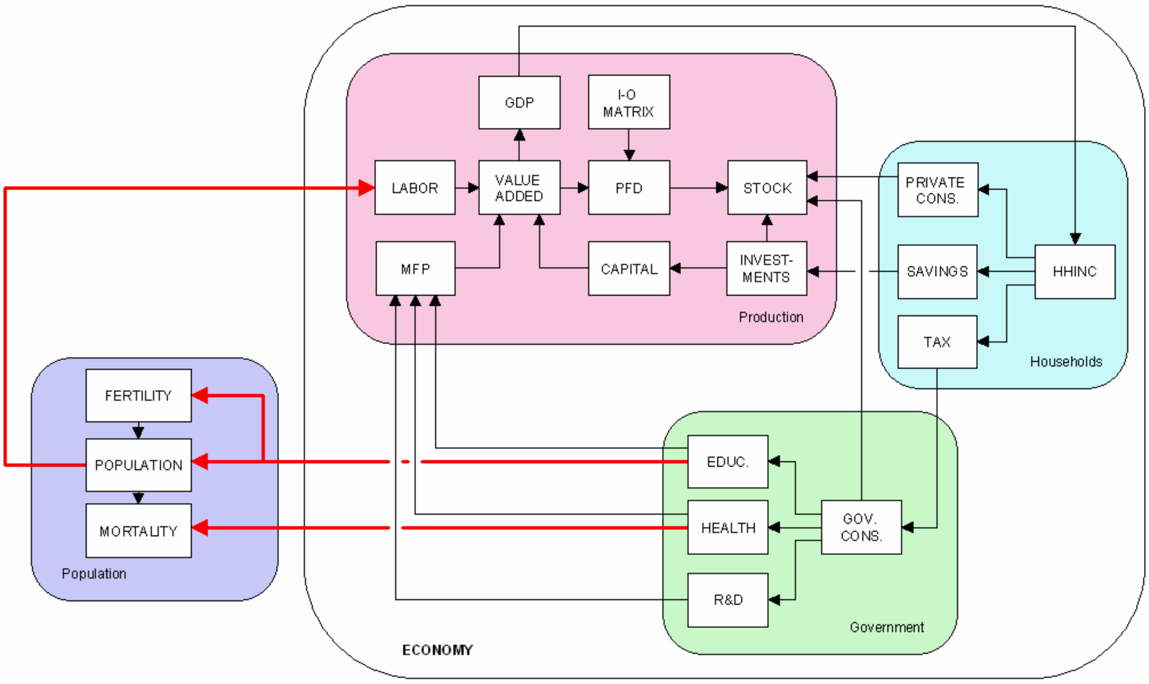



*Figure 16 Schematic overview of the different modules and their linkages in IFs.*

IFs-economy is a general equilibrium-seeking model that does not assume that exact equilibrium will exist in any given year. Rather, it uses inventories to buffer supply–demand mismatches and to provide price signals so that the model chases equilibrium over time. It represents the economy in six sectors and contains a Cobb-Douglas production function. It computes and uses I-O-matrices that change dynamically with development level. Furthermore, it uses a linear expenditure system to represent changing consumption patterns and a ‘pooled’ rather than bilateral trade approach for international trade.

Five sub-modules can be distinguished: a production module, three consumer modules (a household module, a government module and an investment module) and a technology module. The *production module* includes six production sectors: agriculture, materials, energy, industry, services and information and ICT. All sectors are described with a Cobb-Douglas type of production function, which is parameterized for each sector separately. In this way the total VA in each sector is calculated as a function of the multifactor productivity (MFP), sectoral capital and sectoral employment and the sectoral labour–capital shares. Changes in the MFP are determined in the technology module. The structure of the economy is taken into account using an I-O-matrix that is dependent on the development level, which in turn is approximated by per capita income. This I-O-matrix is used to determine gross production, inter-sectoral flows and the production for final demand. Production for final demand is consumed by households and the government and used for investments in the different sectors.

Total inventories are dependent on their level in the previous year, and total production and consumption are determined by the different consumer types (households, government and investments). By mean of comparison to a desired inventory level, these inventories are used as a proxy for relative sectoral prices. These relative prices drive both investment demand per sector and the relative interest rate, which drives consumer behaviour in terms of savings and consumption. The sum of sectoral value added, being total GDP, flows directly to the private households as income. Part of this income is taxed, making it available for public (government) expenditure; the remainder is either saved, making it available for investments, or used for private consumption.

Total tax is collected by the government, which uses the collected money for investments in educational services, health services, research and development and other services (including the military). To determine government investments per sector, total revenues are divided over the different government sectors according to their initial shares. The government module includes certain policy handles with respect to total expenditure or revenues; taxing and total expenditure can be increased or decreased exogenously. Furthermore, the expenditure shares can be altered exogenously, where the shares of the different government sectors can be granted lower or higher priorities.

The consumption ratio – i.e. the percentage of total income used for consumption – is tied to the development level and, therefore, also made a function of per capita income. The remainder is used for savings, which directly flows to the investment module. Total consumption and thereby total savings also further respond to changes in interest rates. Where a higher interest rate makes saving more attractive, this results in decreasing consumption and higher saving rates. A lower interest rate has the opposite effect.

Total savings by the private households are used by firms for investments in the different economic sectors to increase their capital stocks. These capital stocks need to be increased to increase the production potential and replace deprecated capital. The sectoral investments are determined according to the relative investments in the previous year and changes in relative prices (sectoral stock levels are used as a proxy). Higher relative prices result in a higher demand for investments as this implies that the demand to supply ratio is increased.

The objective of a recent initiative within the IFs project was to undertake a significant reworking of the Cobb-Douglas type of production function to better endogenize contemporary drivers of MFP and economic dynamism (Hughes and Hillebrand 2006). The endogenization is mainly based on the work of Chen and Dahlman (2004), who broke down the drivers of the MFP into four categories.

There are two foundational elements in the approach taken by IFs: the specification of basic productivity growth rates and the representation of the productivity drivers for deviation around the basic growth rates. With respect to the basic productivity growth rates, IFs exogenously sets core rates for both the systemic leader (identified now as the United States) and other countries. With respect to deviation around those rates, IFs uses the stylized facts and conclusions about drivers of productivity that have been extracted from the literature to drive them. IFs groups the many drivers of multifactor productivity into the four categories of Chen and Dahlman (2004), recognizing that the categories overlap somewhat. These categories incorporate factors that can either retard or accelerate the basic productivity growth, transforming the overall formulation into one of conditional convergence.

*Projections.* Most recent official macro-economic growth scenarios show an extrapolation of the high growth trends of the last decade. The recent energy report (Planning Commission 2005) has a 7%/yr and an 8%/yr forward projection of GDP, which would increase the average income of an inhabitant of the subcontinent by a factor of four to five between 2006 and 2031. Around 2030, India would thus have reached income levels prevailing in Western European countries in the 1960s and Eastern European countries in the 1990s (compare Annex C). It is difficult to appreciate such income growth, however, because the actual quality of life is influenced by the nature of such growth: income disparities, innovations and their dispersion, infrastructural developments and the trade situation (including the PPP conversion if one wishes to make comparisons, etc.). A more qualitative forward outlook is presented in the Vision 2020 of the Planning Commission (2002). It focuses on human development, discussed in terms of aspirations for food security, employment, education, science and technology capabilities, vocational training and health.

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*Past and future economic growth.* In a recent report, Poddar and Yi (2007) have investigated the factors accounting for India's rapid economic growth during the last decades. Their analysis of macro-economic data indicates that (total factor) productivity growth has accelerated: this may explain half of GDP growth since 2003 as compared to one quarter in the 1980s and the 1990s. In their assessment, the four key factors behind this acceleration are:

- Efficiency increase in the private sector as a consequence of liberalization of the economy and opening up for world trade;
- Rapid rise of the financial sector, which has allowed a more effective channeling of savings into investments and subsequent productivity improvements;
- Rapid expansion of the IT industry, with important spillovers via education and high-tech firms and productivity increases in other firms;
- Infrastructural works under construction, in particular The Golden Quadrilateral – a four to six lane highway connecting the four major metropolitan areas in India;
- The push and pull factors of rural-urban migration have led to an urbanization process which has boosted economic growth; and

– Relatedly, the increase in overall productivity has been fuelled by labour moving from low-productivity agriculture to high-productivity manufacturing and services.

Although all of these factors have played a role, quantitative evidence is difficult to provide. Based on this analysis, the authors present as the rather robust conclusion that India has the potential of 8%/yr economic growth until 2020 – provided it overcomes the major constraints posed by unequal income distribution, underperformance of the educational system and environmental degradation.

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Shukla *et al.* (2003) have presented one of the few scenario-based studies in the context of development and climate. Following the IPCC-SRES approach, they explore possible scenarios along two axes:

- high and low market integration, denoting the extent of liberalization, globalization and integration into the world market, and
- centralized and decentralized governance.

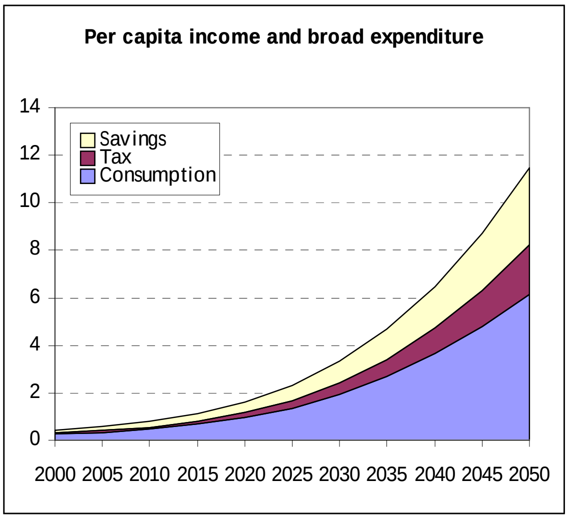
The resulting matrix gives four scenarios, each with its own more or less consistent and plausible narrative. For the high market integration and centralized governance scenario: *IA1 High Growth,* the authors assume a 9%/yr GDP-growth over the period 2000–2030. This is apparently also the assumption behind the Vision 2020 report. Such a high economic growth would imply government-supported market reforms, rapid technological change and the adoption of more 'Western' lifestyles. The population could nearly stabilize by 2030 in such a scenario. People in booming economic regions around high-tech cities like Bangalore and Hyderabad and high-finance cities like Mumbai would associate especially with such a future.

A future with a high and worldwide level of environmental and social consciousness, called the *IB1 Sustainable Development*, emphasizes a more balanced growth path with a more equitable income distribution and more effort expended to limit environmental damage. The transition to an ICT- and service-oriented economy would be even faster than in the IA1 scenario. Average annual GDP-growth would decline from 7%/yr in the first decade to 6%/yr in the third decade of the century. Some associate this scenario with the southern state of Kerala, where a combination of a good social and educational infrastructure – the state has a communist government – and a rather open market economy has led to a stabilization of population growth, among other things.

The third scenario, *IA2 Business as Usual*, depicts a centralized governance with no or only limited market reforms. This is argued to reflect present-day government policies in India. This scenario characterizes the future by less trade, slower technological change, "low globalization and liberalization restrained by the democratic forces in the country", regionalism, mass unemployment and income gaps and a desire for resource independence. Because of an emphasis on family and community life, the population grows faster and may exceed 1.4 billion people by 2030 (compare with *Figure 12*). GDP-growth is assumed to fall from an average 6%/yr to 5%/yr between 2000 and 2030. Some would associate this future with the current outlook in the large, backward and poor states like Bihar and Orissa with the 'Hindu rate of growth'.

The fourth scenario combines fragmented market integration with decentralized governance: *IB2 Self-reliance*. This low-growth scenario emphasizes local and regional quality of life aspects in a broad sense. It includes regional decision-making and institutions, local level environmental concerns, community support networks that constrain social and economic inequity and an aspiration to be resource-independent. The rather low GDP-growth rate of 5%/yr, falling to 4%/yr by 2020–2030, is less the result of failures – as in the IA2 scenario – than a conscious choice for particular quality of life aspects. In this scenario in particular, GDP is an inadequate measure of performance (De Vries 2006).

*Results.* Some preliminary model results are presented below (see also Annex E). The model run for India has been calibrated to a threefold increase in per capita income between 2000 and 2020, which is somewhat lower than the Vision 2020 report (Planning Commission 2002) and in line with scenario B1 of the IPCC-SRES and the IB1 Sustainable Development scenario by Shukla *et al.* (2003) discussed above. One interpretation is follows the storyline of this IB1-scenario: the corresponding savings and taxes are assumed to be effectively implemented as are the gradual increase in expenditures on health services and education over the next decades (*Figure 17*; compare *Figures 14, 15)*). The exponential nature of the GDP-growth dynamics in macro-economic models generates a further doubling of income in every decade – one objective of the present project is to explore the threats and opportunities for such a pathway.



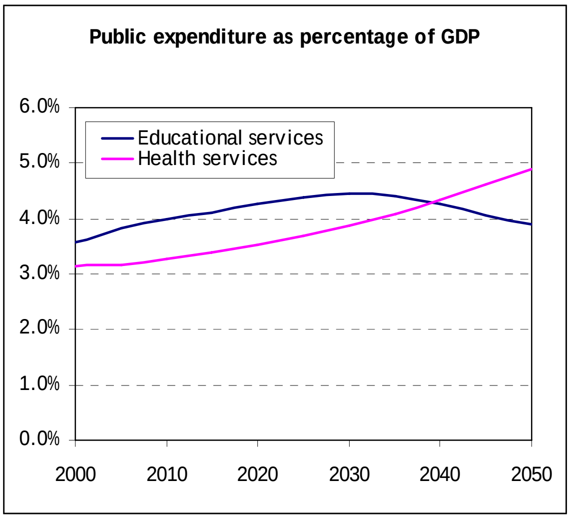




*Figure 17 Growth of per capita income and of public expenditures on health services and education for India 2000–2050 in a high-growth future.*

### 4.2.3 Food and water

*Food.* The aim of part of the Workshop organized in June 2006 at MNP was to analyse the food situation in India over the next decades (Bhat 2006). To this end, the participants in the Workshop explored the development of three broad food demand and supply scenarios:

1. a Business as Usual (BaU) Scenario;
2. a transition to (bio)technology and capital-oriented agriculture and water management with linkage to regional and global food markets (TTC);
3. a transition to 'sustainable' water, energy and biomass systems (WEBS) with linkage to local and sub-regional markets (TS).

A rather straightforward agricultural model has been constructed using the district as the basic unit for modelling. The districts are classified on the basis of hydrogeology, climatic conditions, food grain productivity, gross irrigated area/geographical area and the state of agricultural development. There are four sub-models. Some of the key assumptions are:

- gross irrigated area (GIA) > total cultivated area (TCA) > total food grain area > food grain yield > food production;
- moderate growth rates in GIA, TCA and yields;
- yield limits for each region type;
- no change in net sown area (NSA) envisaged;
- land diversion changing each decade (faster after 2010) with a maximum of 10%/decade in arid and semi-arid regions.

Some limitations of the approach are:

- uncertainties in data;
- different formats of reportage from different regions;
- uncertain future policies;
- uncertain terms of conflict resolution;
- Northeast and Jammu and Kashmir (J&K) data either not available or unreliable.

For each of the three scenarios explicit assumptions have been formulated.

Key elements in the BaU Scenario 1 are:

- low efficiency of water use, moderate growth in GIA and TCA;
- low yield limits;
- shift to non-food crops in high-risk environments;
- moderate diversion of land for nonfood crops;
- maximum 10% decadal after 2010 in arid and semi-arid regions;
- rest of the areas is 2–5%;
- farmer lobbies have the ability to dictate;
- individual investments on water resource development.

Key elements in the the Biotech (TTC) Scenario 2 are:

- additional growth in yields of 5–10% per decade growth in different regions;
- drought-resistant crops leading to additional 2%/decade growth in cropping intensity;
- crop yields: agriculture in degraded lands may not be food grains;
- slow yield response except in irrigated belts;

- investments in few cereal crops as in the past and neglect of millets.

An additional Scenario 2a has been formulated with: an additional 4%/decade cropped area diversion for non-food grain crops.

Key elements in the improved water and land management Scenario 3 (TS):

- better land and water management;
- conjunctive use of ground and surface water resources;
- no change in yield limits;
- additional 2% decadal growth in GIA in all regions;
- improved water use efficiency leading to 5% additional increase in TCA.

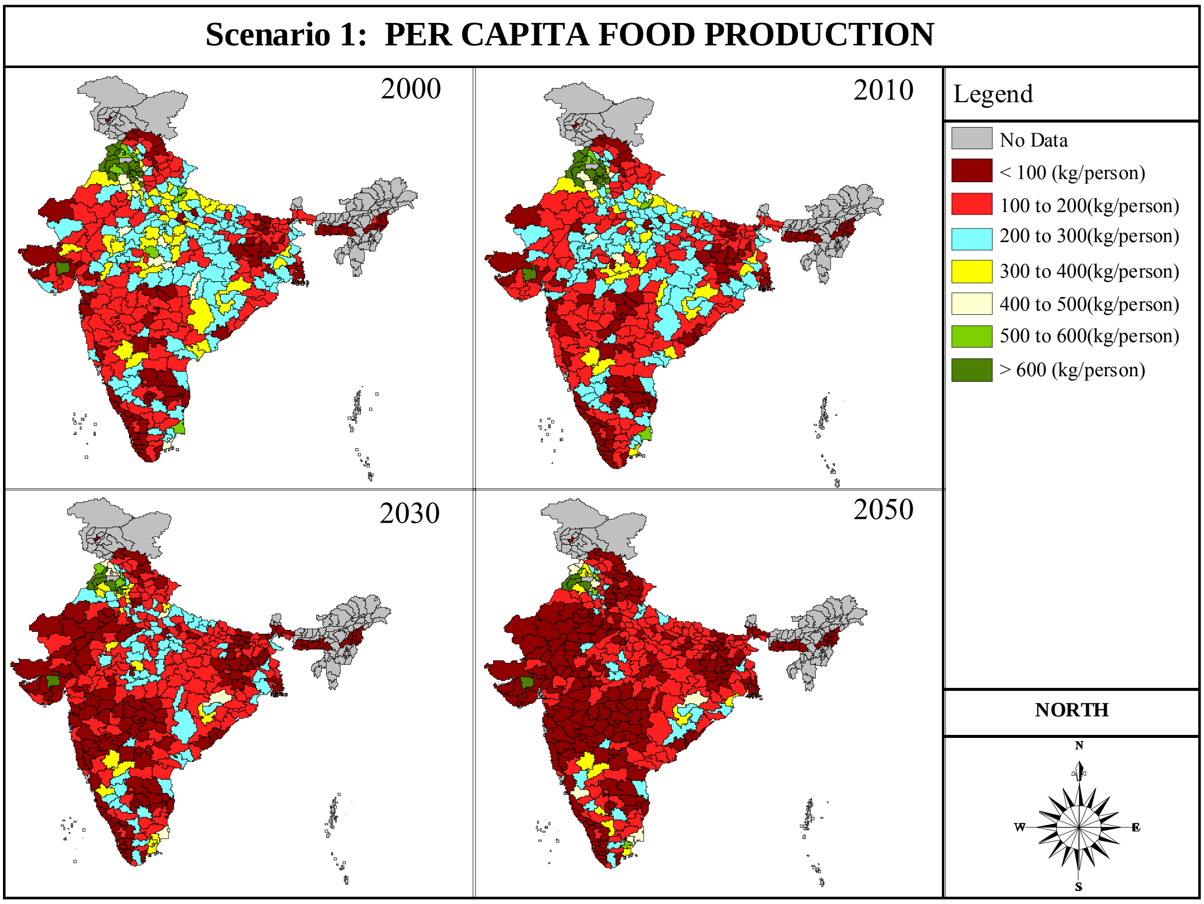
The outcome of these calculations for a number of food/agriculture-related variables are given in Annex F and *Figure 18a, b*. The time series show the trends in food grain production and cropped and irrigated area. Based on these scenarios, is it is quite clear that the food supply situation for the Indian population will become more tense in BaU Scenario 1 but also in a situation where large areas are diverted from food to non-food crops (Scenario 2a). The latter consideration may affect the potential for large-scale biofuel plantations. The series of maps show the per capita food production and per capita TCA at the district level. These maps provide indisputable evidence of the enormous pressure on the food and land in India with a further rise in population and associated aspirations for a decent level of food supply. Unfortunately, these forward projections can not (yet) be related to the economic growth projections – one important avenue for further research is the linkage between the biophysical facts and prospects on the one hand and the economic development, in terms of I-O- and SAM-matrices on the other.

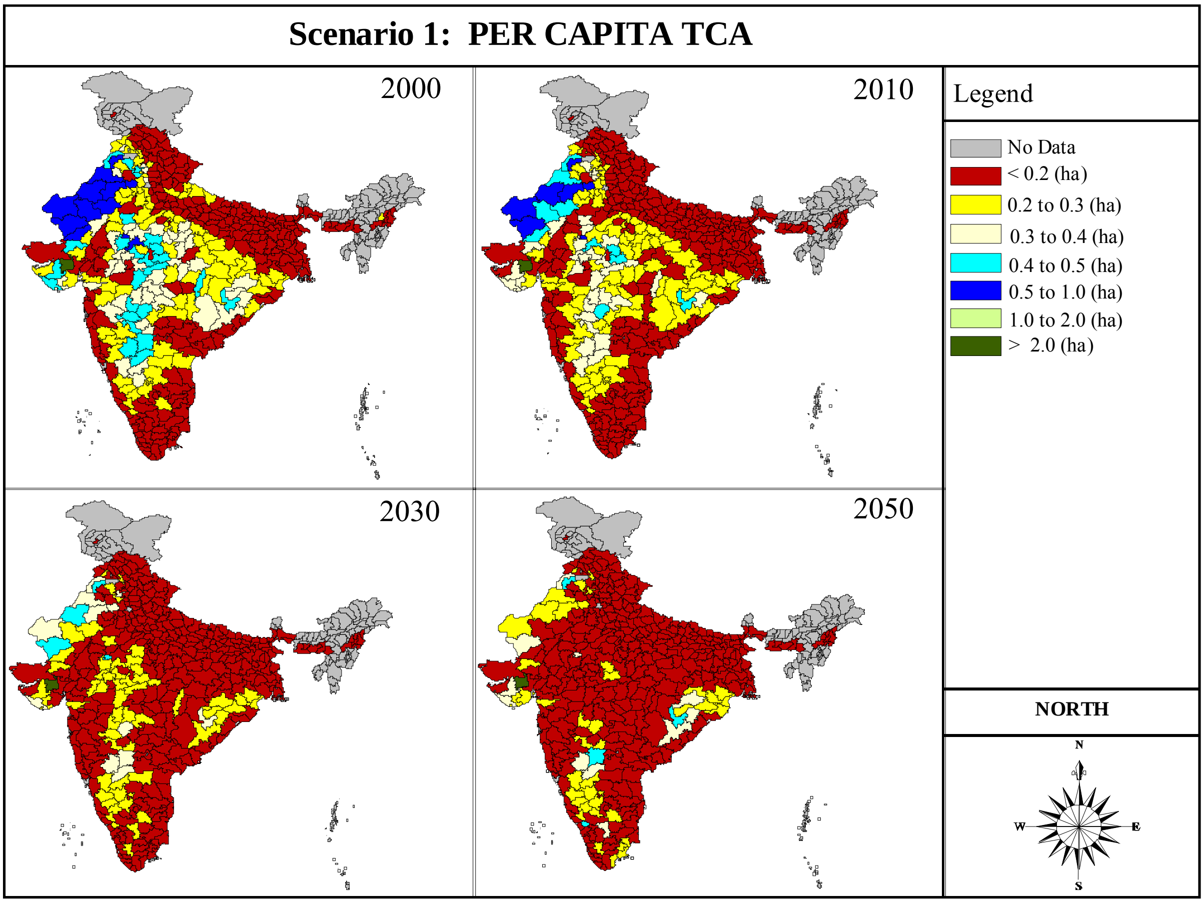
The major *conclusions* from this scenario exercise in terms of India's food prospects for the next half century are:

- Land and water resource are the two main constraints;
- Better water management can help ensure food self-sufficiency;
- Shift to cash crops can severely impact food self sufficiency;
- Non-agricultural livelihood options will be necessary to support rural population.

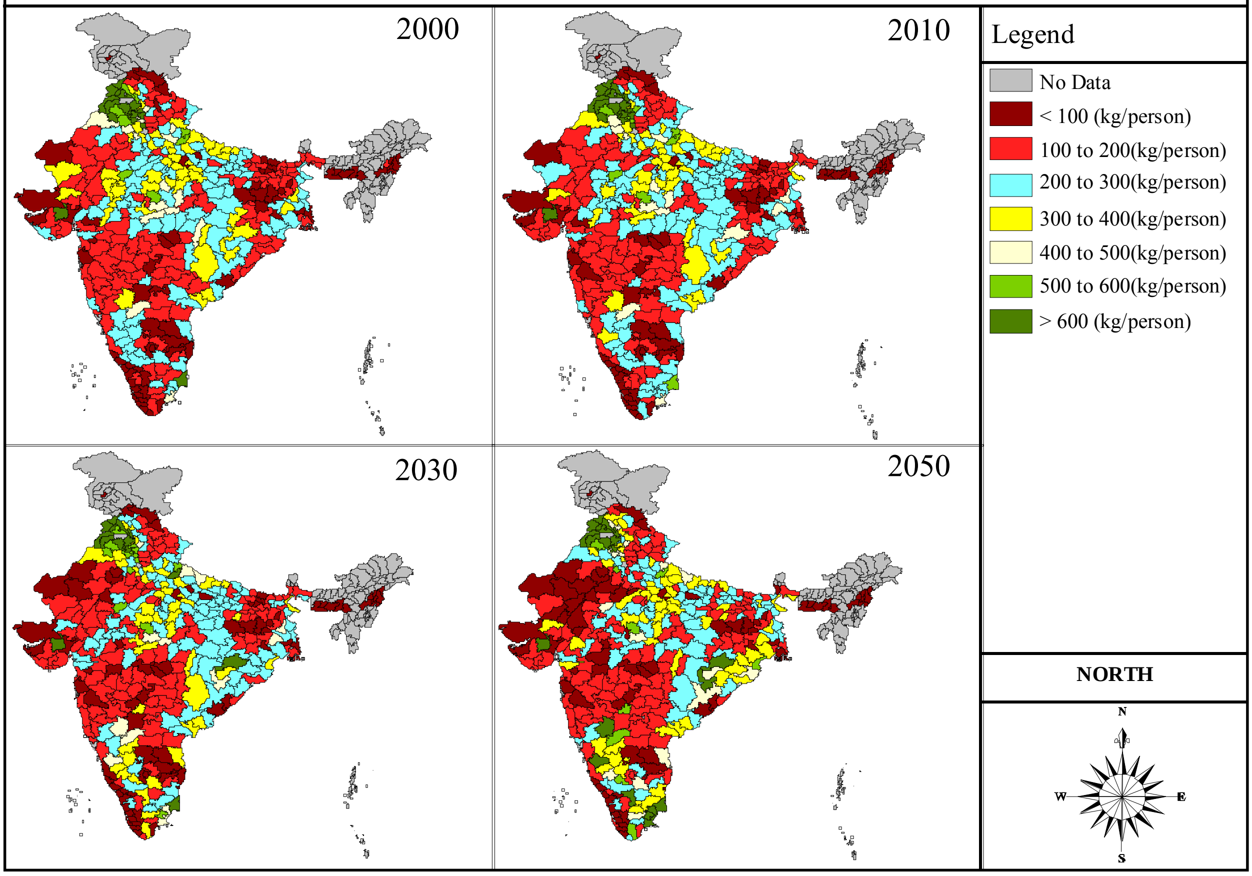
Over the past decade, projections on land cover/land use and food production and consumption have been made in many other studies, including scenario exercises with the IMAGE-model in the context of climate policy (Alcamo *et al.* 1998, De Vries *et al.* 2000). A more recent version of the IMAGE-model is under constructon, with the results expected to be available in the course of 2007. Another source of forward projections is the National Commission on Farmers and the Ministry of Agriculture of the Government of India whose projections generally fall within the range of the scenarios discussed above.

*Figure 18a Scenarios for per capita food production and per capita cultivated area (continued).*

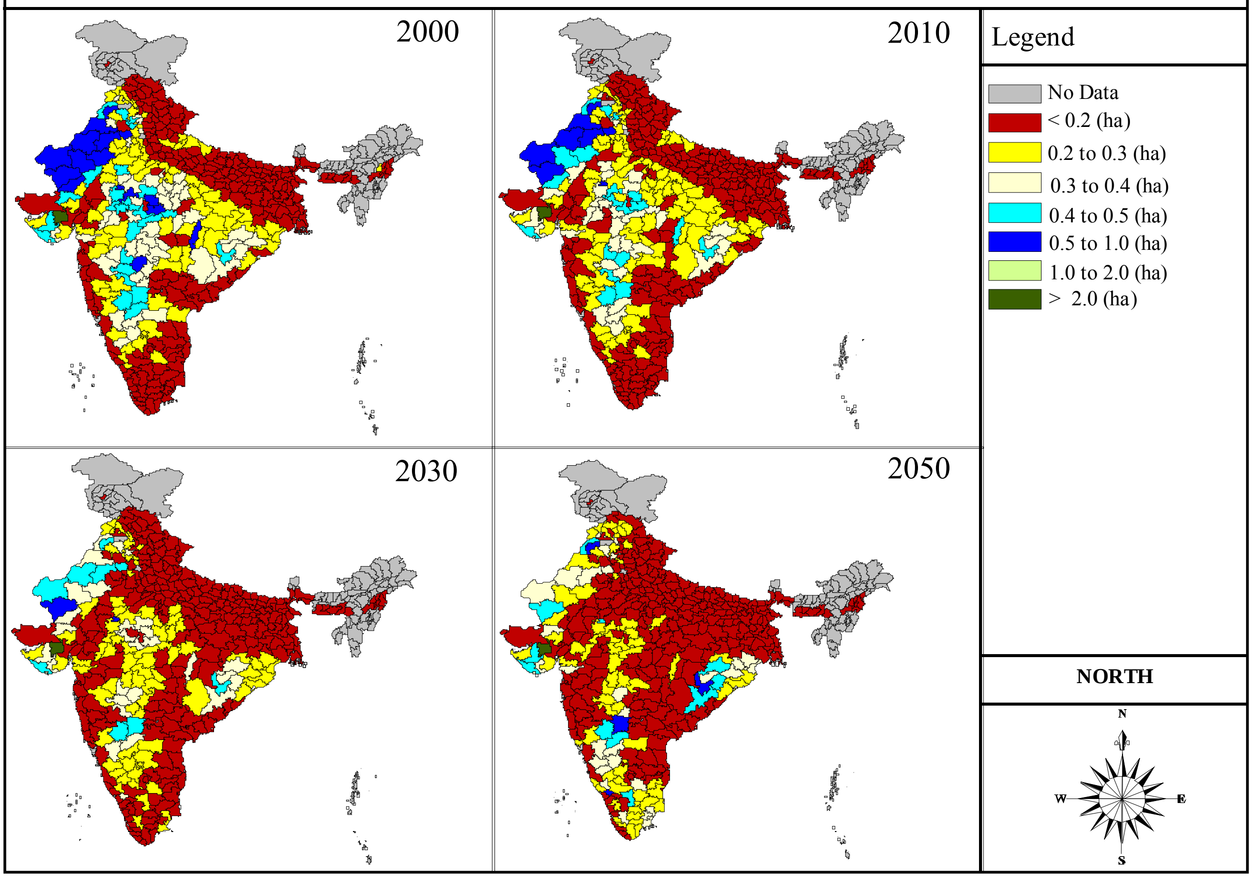


## Scenario 3: PER CAPITA FOOD PRODUCTION




## Scenario 3: PER CAPITA TCA



*Water*. Water resources of India are unevenly distributed over space and seasons. While the Indo-Gangetic plains have surplus water resources, the rest of the country faces seasonal water shortages. Droughts are quite common and affect at least one part of the country almost every year. With the development of groundwater extraction systems, such as deep bore wells, the water scarcity has been reduced for some years, but overexploitation of groundwater is currently a major concern in many hard rock regions of the country. Overexploitation of groundwater has increased vulnerability to droughts in hard rock and semi-arid regions.

Water scarcity is expected to grow with continued extensification of irrigation through groundwater extraction and a shift to water intensive crops. Seasonal water scarcity is likely to grow and expected to cause shifts in agriculture and settlement patterns in the next two decades. Water scarcity has remained to be a major concern for the government in both rural and urban areas. With the expansion of urban areas, the water conflicts between rural and urban areas are likely to become major issues in many parts of the country.

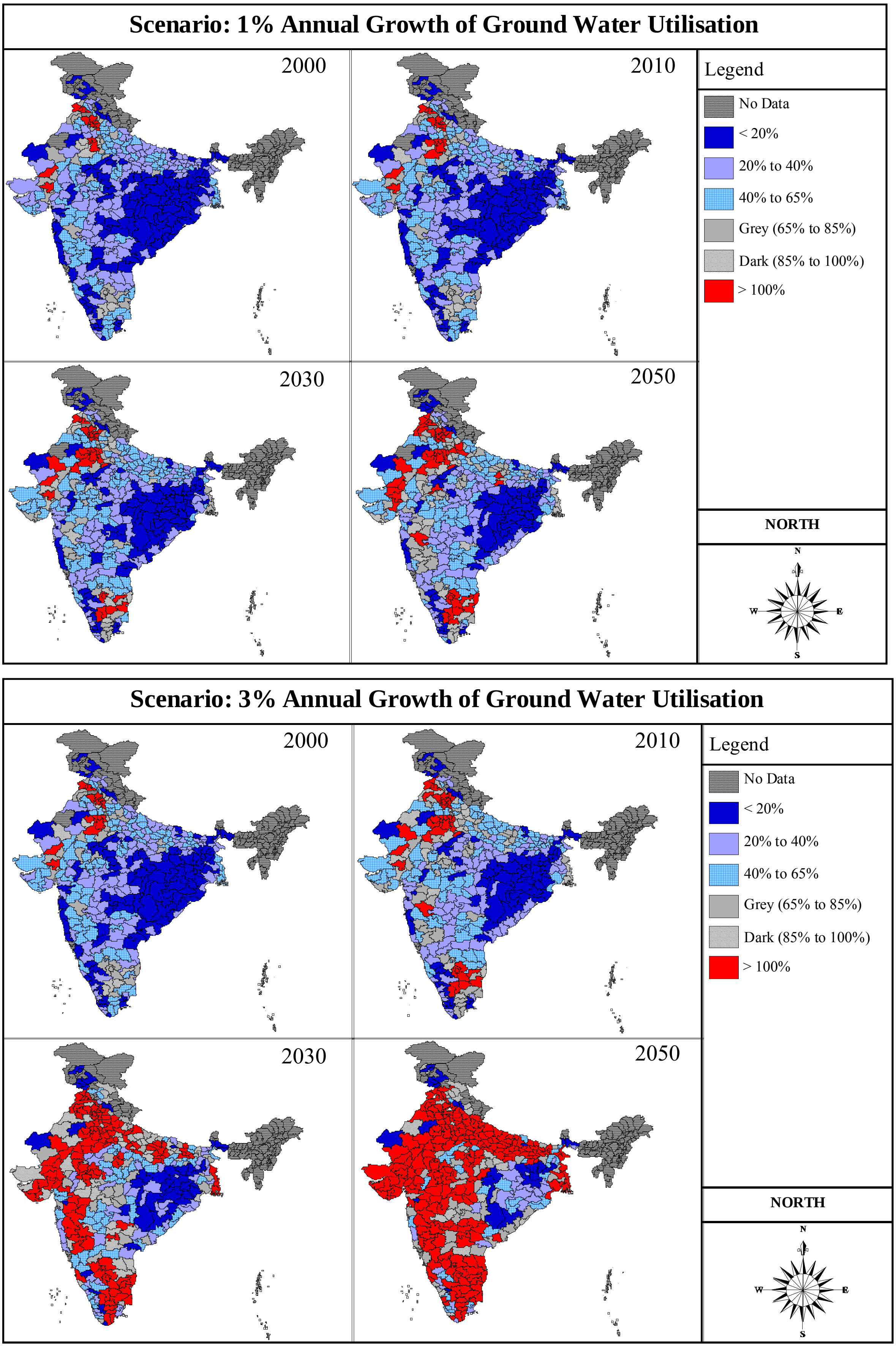
The scope for increasing storage of surface water is limited and already there is growing opposition to developing new water resources due to issues of resettlement. Inter-state water disputes are likely to increase the pressure on existing water resources. Per capita water resource availability has already reached critical limits in many river basins. Large parts of Semi-arid and Arid regions are likely to face growing water related conflicts at various levels.

Using the district as the unit of analysis and 1995 as the reference year, three growth trajectories for the use of ground water have been investigated. Here, again, the outcome is shown in a few maps at the district level (*Figure 18b*). In the case of a 1% annual growth in ground water use, which is possible with power subsidy reduction, stress on the available ground water resources will be serious in several regions. If, however, the events as observed in the peninsular and Indo-Gangetic region during the last decade are continued over the next decade, a 3% annual growth will occur. This will undoubtedly lead to unsustainable situations within 50 years from now. A development that would reflect the prevailing scientific insights in resource availability together with the corresponding response policies and behaviour could reduce or at least stabilize the tensions. In all cases, however, major ground water droughts in almost all areas by 2010 are to be expected. The water use projections are in a number of ways linked to the food demand and supply scenarios and the macro-economic growth projections – another item for further research for an integrated assessment modeling and planning framework..

### 4.2.4 Energy

*The TIMER-model.* Since 1998, MNP has been making forward calculations of energy system developments with the TIMER-model, which is the energy model of the IMAGE-framework. For information on model construction and results of a variety of simulations, we refer to De

*Figure 18b Ground water depletion for a 1%/yr and 3%/yr increase.*



Vries *et al.* (2001) and the IMAGE website at MNP (http://www.mnp.nl/image/model_details/energy_demand_supply).

*Projections.* In the Planning Commission document Vision 2020, it was stated that India's installed capacity for power generation had tripled between 1980 and 1997 and "even under the best-case scenario (BCS)" another tripling of generation capacity from 101 GWe in 1997 to 292 GWe in 2020 is necessary (Planning Commission 2002). At least two-thirds of this expansion would have to come from fossil fuels, with the associated rapidly rising (cost of) imports because even doubling domestic coal production would not meet demand. Oil imports could triple between 1997 and 2020 – almost all for transport. This estimates used in this report in terms of oil price are rather dubious in that the report quotes a Japanese report estimating oil prices to be in the range of 17–23 USD/bbl – obviously they did not foresee the price rises since 2003. A large increase in natural gas use was projected to happen as well, mostly for power generation and industry and, in particular, for fertilizer production. Hence, planning for massive natural gas imports was called for.

A more recent projection for energy use in All India up to 2031 is given by the Planning Commission (2005). Based on estimated growth elasticities of between 0.67 and 0.8 and an average GDP growth rate of 7%/yr and 8%/yr, respectively, total primary (commercial) energy supply (TPES) is projected to increase by a factor of 3.5–4.3. For electricity, it is even higher, implying an additional peak capacity of 425–675 GWe between 2006 and 2031. This amounts to the construction and operation of as additional 24 and 33 1000-MWe power stations per year, respectively. Quite a few other studies have been made on India's energy and electricity future, some of which have emphasized the need for efficiency and small-scale and renewable options (e.g. Balachandra *et al.* 2003).

Although it will not be impossible for India to meet the increasing demand for energy, for such a densely populated country, it is a daunting challenge – made even more so by two additional constraints: (1) increasing tensions associated with oil and gas supplies as demand keeps soaring and world resources are depleted; (2) the growing concern about the large carbon emissions associated with the use of fossil fuels and, in particular, India's most abundant fossil fuel: coal. One possible scenario (Planning Commission 2005) projects an increase in coal use from 318 million tonnes/yr in 2003 to 1096 (7%/yr GDP growth) and 1478 (8%/yr GDP growth) million tonnes/yr in 2031. Despite this vast expansion, which will require huge surface mining operations and ash handling flows, the share of coal in the energy-for-electricity declines from 85 to 78%. At the same time, hydropower electricity has to increase five- to six-fold, whereas an additional 75 1000-MWe nuclear power stations are to be in base-load operation.

The resulting primary energy requirement will – under these assumptions – increase to between 1340 and 1630 Mtoe/yr by 2031. An additional 185 Mtoe/yr is thought to be used as non-commercial fuel in mostly rural households. Despite this growth the average Indian person will still use in 2031 less than one-fourth of what the average inhabitant of the OECD-region consumes at the present time. One side-effect of this development would be an increase in carbon emissions from the present 375 MtC/yr to values in the range of 1200 to 1600 MtC/yr by 2031 (Planning Commission 2005). The upper range is for a world in which the maximum use of Indian coal were the objective – whereas the lower range is projected from a set of alternative scenarios in which a mix of efficiency, nuclear expansion and/or renewable expansion is implemented.

One recent study on energy use for passenger transport and the associated carbon emissions fits well into this kind of forward outlook (Kumar Singh 2007). Using a logistic growth extrapolation of the key aspects of the transport system – mobility and modal split – the author found that motorized traffic volume in India may well increase from 3,500 billion pass-km in 2000 to 13,000 billion pass-km by 2020. Over 90% of this would be by road, and energy use for passenger transport would increase from 1,060 to 5,585 PJ/yr in this period. An additional 73 million tonnes of carbon would be emitted per year if this development takes place – roughly 20% more than the present emission in a country like the Netherlands. As mentioned earlier, one of the problems with such forward projections is that they are at the aggregate level of All India. At the more disaggregate level of large cities and rural areas, it appears that the available data are rather patchy and seldom used for detailed forward outlooks.

*Results.* Recent calculations were carried out for the OECD Environmental Outlook 'baseline scenario', with the driving forces as assumed in the IEA Energy Outlook 2005 [9]. These are shown in *Figures 19* and *20*. The calculated primary energy use and installed electric power capacity pathways suggest that the projection of the Planning Commission (2005) tells the high-growth high-tech story. Indeed, the earlier estimate of 292 GWe by 2020 is close to the TIMER calculation for the A1b/B1 scenario (Planning Commission 2002). Given our parameterization of costs and technologies, a continuation of the high-growth path in this future would cause a gradual shift after 2030 towards coal, nuclear and renewables – including commercial biofuels – as a result of worldwide oil and gas depletion and learning-by-doing cost decreases in the non-fossil options. Although the uncertainties about conventional and, in particular, unconventional oil and gas deposits are large, such a shift would appear to be quite probable in an A1 future. The question then is whether India could deal with the concomitant effects of climate change impacts and increasing land use.

The model results suggest that a much more vigorous effort to introduce energy efficiency and renewables as part of a less material- and energy-intensive economic growth could prevent – or at least slow down – some of the tensions. Such a development would have to be supported with no-regret and co-benefit options like stringent air quality standards, public

[9] Simulation results with the TIMER-model in the context of the SRES-IPCC scenarios (De Vries *et al.* 2000; Van Vuuren *et al.* 2003) are shown for South Asia in Annex G for the A1b (left) and B1 (right) scenario, respectively, up to the year 2100. A1b stands for A1-balanced. The results are for the region South Asia, which includes India, Pakistan and Bangladesh. The more recent TIMER version simulates India separately.

transport promotion and leapfrogging ICT-trends (De Vries *et al.* 2000; Metz *et al.* 2002; Van Vuuren *et al.* 2003). In fact, the Vision 2020 document of the Planning Commission (2002) stresses the both need for and the potential of a more aggressive, massive commitment to the development of renewable energy. The prospects for a national network of small, decentralized biomass power plants in the 10- to 25-MWe range are emphasized – an estimated 40 million ha could provide 100 GWe of power and year-round employment for 30 million people. In addition, biofuel from plants and trees could help to make India less dependent on oil imports: 10 million ha could generate 7.5 Mtoe/yr and year-round employment for 5 million people. One assessment indicates a potential of 5–24% of projected energy use by 2010 coming from eucalyptus plantations (wood) with a carbon emission reduction in the range of 25–125 million tonnes C/year; similarly, large amounts of biodiesel could come from jathropa plantations (Hooda and Rawat 2006). The government's ambitions are on the rise – for example, a 2003 programme aiming at 20% of petrodiesel to be replaced by biodiesel – but there are still serious barriers with respect to technology, financing and marketing to overcome. Creating tens of millions of rural jobs and stimulating growth of rural incomes are seen as the greatest advantage, but also energy security, air quality and biodiversity considerations are mentioned, which constitute three parts of the B1 Scenario outlined in the SRES-IPCC (De Vries *et al.* 2000).

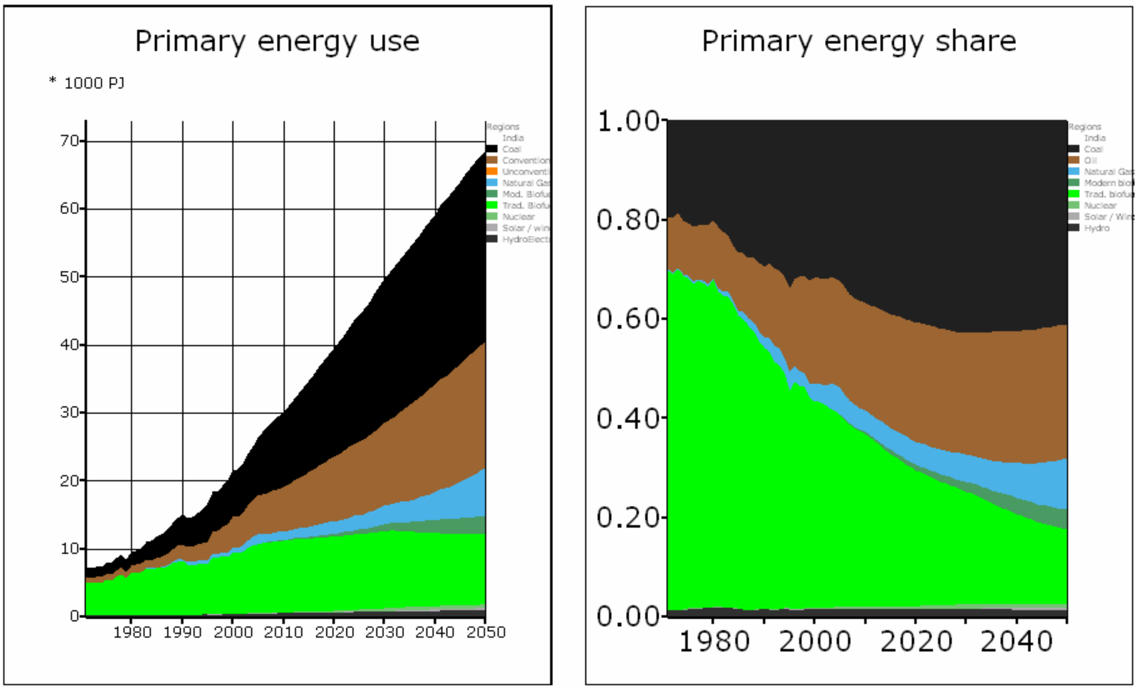



*Figure 19 Simulation with the TIMER-model of primary energy use in India in the OECD Environmental Outlook baseline scenario. Notice the large share of traditional fuels.*

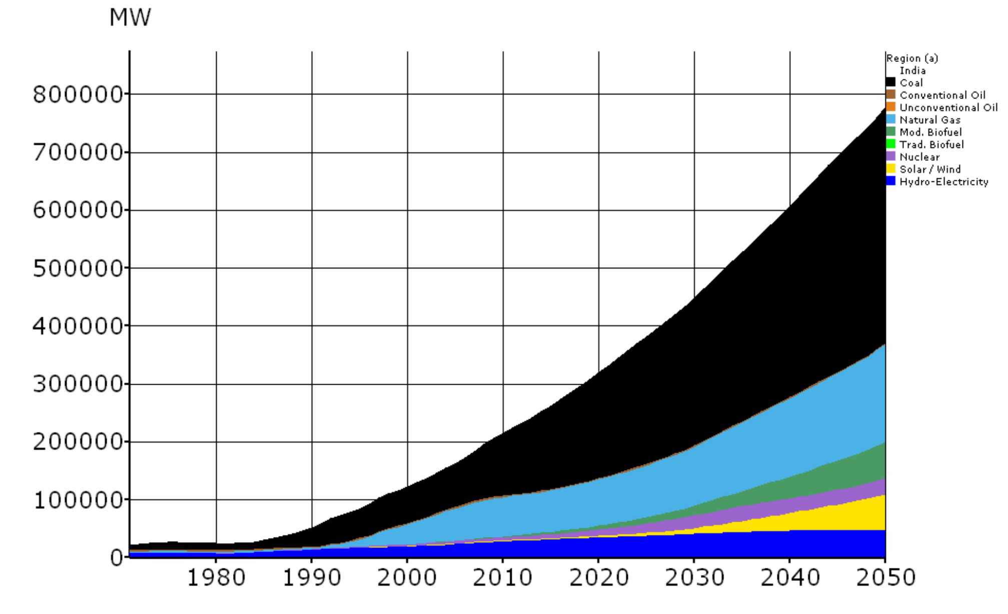



*Figure 20 Simulation with the TIMER-model of installed electric power capacity in India in the OECD Environmental Outlook baseline scenario. Notice the large share of coal.*

As *Figure 21* shows, the simulated trends in energy production are significantly below the projections made in the Planning Commission (2005) report. This probably reflects a more optimistic GDP growth rate and a higher growth elasticity in the Planning Commission study. The simulated results also clearly show the important role of traditional biomass-based fuels in India – also for the decades to come – and the growing role of oil and gas in energy use and a corresponding growth in oil and gas imports.

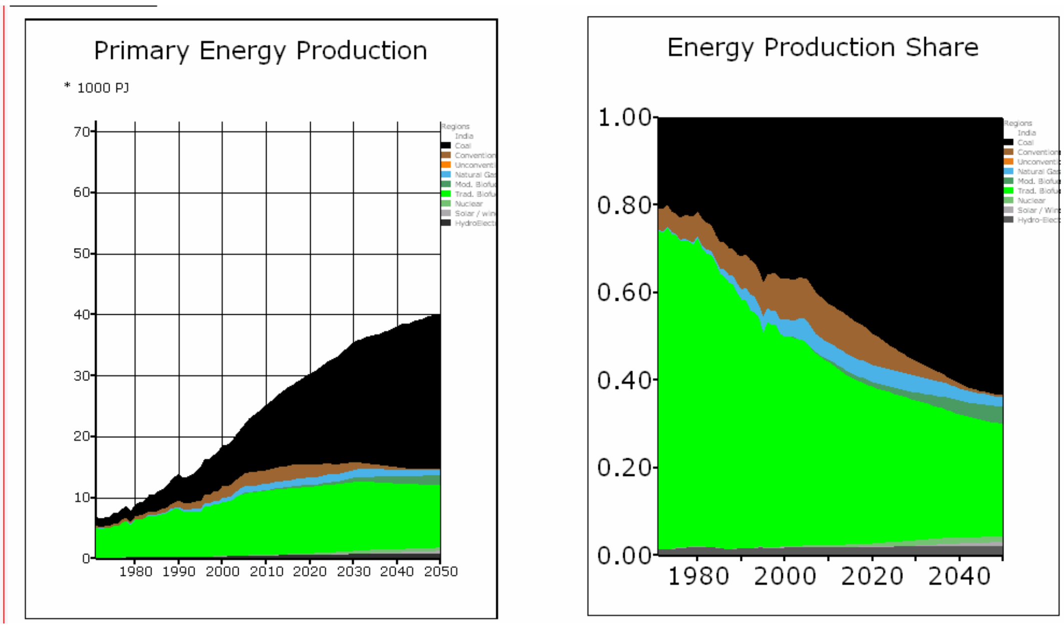



*Figure 21 Simulation of the primary energy production in India for the OECD Environmental Outlook baseline scenario. Notice the important role of traditional energy sources.*

A comparison of these results with the analysis done by Shukla *et al.* (2003) reveals several similarities. The OECD baseline scenario projects 50 EJ/yr for India in 2030, which is in the range of the IA1 scenario (53 EJ/yr for India), suggesting that the IEA-OECD assumptions are in line with a high-growth high-tech world (*Figure 19*). However, there are apparent differences in the fuel mix: in the OECD baseline scenario the fossil fuel input, which is about 36 EJ/yr, is below that of the IA1 scenario (26, 15 and 4 EJ/yr for coal, oil and natural gas, respectively), the role of natural is significantly larger and the use of traditional biofuels is unclear.

In terms of the energy supply and carbon emission situation, the forward calculations by Shukla *et al.* (2003) lead to the following observations:

- In all scenarios, there is a large increase in fossil fuel use, but it is by far the highest in the IA1 scenario. The IB2 scenarios tend to have the lowest use of fossil fuels. Carbon emissions are expected to increase from about 260 million tonnes/yr of carbon (MtC/yr) in 2000 to about 850 and 560 tonnes/yr in the IA1 and IB1 scenarios, respectively. The IB1 scenario assumes that future carbon mitigation policies will be implemented. Both estimates are significantly below the recent range of carbon emission estimates in 2030 by the Planning Commission (2005);
- In the IA1 scenario, coal use is assumed to exceed 900 million tonnes/yr in 2030, oil, 370 Mtoe/yr and gas 130 bcm/yr. The higher coal use than in the TIMER simulations highlights one of the crucial elements in India's energy future: the role of indigenous coal and imported gas (and oil). A similar question marks China's energy future (Van Vuuren *et al.* 2003);
- In all four scenarios, electric power generating capacity will increase several fold, but again the largest increase is in the IA1 scenario. Whereas in the IB2 scenario an additional 150 GWe will have to be supplied between 2000 and 2030, in the IA1 scenarios, this is in the order of 275 GWe – one 800-MWe plant every month. These results tend to be rather low in comparison with the TIMER simulation results for the corresponding scenarios: an additional 330 GWe between 2000 and 2030 (*Figure 20*).

# 5 India 2050: forward projections with the IFs model

## 5.1 The IFs model

The IFs model is a tool for thinking about long-term global futures, as already indicated in the previous chapter (http://www.du.edu/~bhughes/ifs.html, Hughes and Hillebrand 2006; Lucas and Hilderink 2005). It originates from the earlier GLOBUS-model which aimed at a formal approach to analysing problems of war and political alliances. The IFs model can be used to study: (1) individual social conditions, (2) collective social conditions and (3) the extent of nationalism and violence surrounding both of the former. To this end, it includes several sub-modules as presented in *Figure 22*. The economic submodel of IFs has been rebuilt in the simulation language 'M' at MNP by Lucas and connected to the population model PHOENIX constructed by Hilderink in connection to newly developed sub-models for education and health services. These models are still under development. The purpose is to provide an overarching economic framework for the MNP-models on climate, land use land cover and food (IMAGE-TES), energy (TIMER) and population and education/health (PHOENIX). In this section we focus on the outcome of a series of simulations for India with the IFs-model version 5 (18 June 2005).

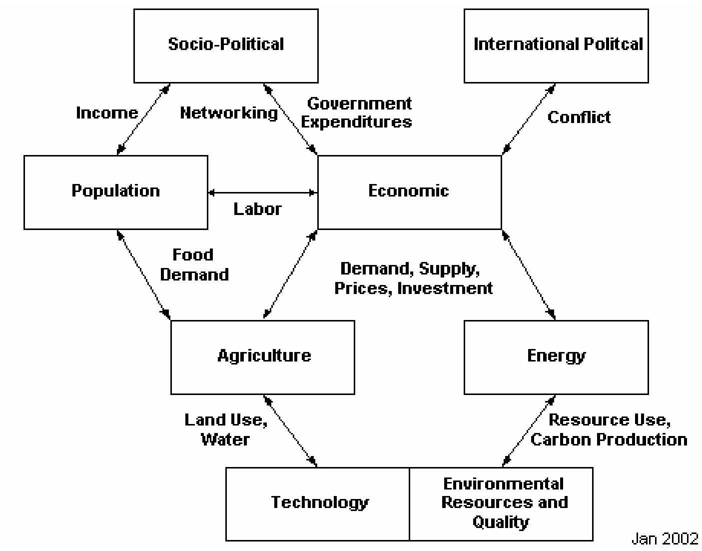



*Figure 22 Overview of the IFs model (Hughes and Hillebrand 2006).*

| **International Futures** | |
|---|---|
| Author(s) | Barry Hughes, Graduate School of International Studies, University of Denver (Hughes, 1999; Hughes, 2001) |
| Website | http://www.ifs.du.edu |
| Time horizon | 1960–2100 |
| Spatial disaggregation | User-defined (default 162 Countries) |
| Modules | Population, economy, agriculture, energy, socio-politics, environment, technology |
| Key stocks | Human population, GDP, agricultural stock, food stock and energy inventories and reserves |
| Scenario evaluation | Basic report with main indicators per module, population distributions, cohorts of the World Value Survey, Social Accounting Matrix and Advanced Sustainability Analysis |

IFs is a multi-regional model built on a database for 162 countries. Countries/regions are related to each other through migration, international financing (industrial and agricultural imports and exports, debts and foreign aid) and co-operation or conflicts. The database allows cross-sectional and some longitudinal analysis of relationships among variables. It also provides a mapping capability both for data at a country level and for forecasts at a regional level. Because countries such as India and China are so large and dominant, an attempt is made to apply the IFs model at a more disaggregated state/region level. There are as yet only results for All India. In terms of sub-modules, the population, economic, agriculture, and energy systems are the most developed.

The population module is a cohort-component population model that dynamically represents fertility and mortality (compare Section 4.2.1). The model uses income, measured as GDP per capita, for the one-way causal determination of income inequality. The latter is indicated by the income share of the poorest 10% or 20% of the population, or the population below the poverty line of USD 1 or 2 per day. Correlations between income and all kinds of social indicators, such as literacy, fertility rate, life expectancy and democratization, are also used to drive social developments. Even the cultural evolution indicators from the World Value Survey[10] (WVS) are used in this way. Life expectancy, literacy and infant mortality are used to compute the Physical Quality of Life (PQLI), an indicator of the Overseas Development Council.

The economic module is a five-sector general equilibrium module with a Cobb–Douglas production function, a Linear Expenditure System (LES) consumption system and inventories to buffer production and consumption over time (compare Section 4.2.2). The agricultural and energy modules are partial equilibrium systems that replace the appropriate sector within the economic module when they are activated. The agricultural module represents land use in multiple categories and distinguishes production, consumption and trade in crops, meat and fish. The energy module represents the production, consumption and trade of multiple energy forms, both renewable and non-renewable.

In terms of the access vulnerability and thereby people in danger, in the IFs models it is the caloric needs of the population – and not the access to or availability of food as derived from the agricultural model – that determines nutrition-related infant mortality. The model has an indicator of water use per capita, but not of access to and availability of water; hence, it cannot assess possible shortages. The same holds for energy, where energy demand is satisfied (demand equals supply) without addressing the problems related to access to and shortage of energy. This is true for most models. An interesting feature is the inclusion of governance and stability, which are related to a threat level, controlled by power and non-power terms, and can lead to conflict or war. These indicators are mainly driven by the level of GDP per capita. The model thereby includes social and political indicators, although the desired indicator framework is not yet fully represented.

[10] The World Value Survey (WVS) is a global project, based at the Institute for Social Research ate the University of Michigan, which was founded by Ronald Inglehart.

We have explored the simulations for India with the IFs model in detail with the aim of evaluating its suitability as a tool for the objectives of the India 2050 project. The IFs model was chosen after a brief assessment of a number of other integrated assessment models, such as the Threshold-21 country-model. The evaluation has also been put in the context of the existing IMAGE-TIMER modelling framework at MNP (see Chapter 1 and www.mnp.nl).

## 5.2 IFs simulations for India

The IFs-model allows the user to run a large array of scenarios. It has an excellent model description accessible via the Help Menu. For the present exploration we have chosen the Base Case scenario and the four GEO-3-related scenarios Markets First, Security First, Policy First and Sustainability First [11]. The IFs-model uses generalized relationships based on cross-country correlations. As it has not been calibrated for past decades, the outcomes may deviate significantly from the trends that one would expect – more for some countries than others, and for different reasons. It is also important to realize that the IFs-model simulates 162 countries and their interactions, which means that a change in the assumptions for one country will have indirect impacts on its future development path via its (trade) relationships with other countries. Although such an attempt at generic relationships to describe country-level developments has the obvious advantage of being able to take interactions into account, it also implies that large regions like India and China are supposedly following trajectories extracted from cross-country time-series for a large group of – sometimes far smaller – countries. Thus, a scrupulous analysis of the results for |India is currently in place. Model simulation results for India 2000–2100 with the IFs 5.18 model version are shown in Annex H.

*Population.* The demographic module is a 22-cohort model with birth and death rates and migration rate. Fertility is driven by income (GDP/cap) as well as by (user-based) influences from income inequality, contraceptive use, convergence trends and changes in values and technologies. Mortality stems from an income-based relationship with life expectancy and a consideration of deaths related to warfare, AIDS and, possibly, starvation via infant mortality. The latter is by means of the ratio of available food and required food. Government health expenditure levels are also considered to influence the death rate.

In the IFs-simulation the Indian population increases to somewhere between 1.3 and 1.7 billion people depending on the scenario, after which it slowly declines. In most scenarios the urbanization rate increases linearly to 90% by 2080; this is a large acceleration as it took 40 years for the urbanization rate to increase from 18% (1960) to 28% (2000). Life expectancy exceeds 80 years on average around 2065–2075, which stems from a number of factors,

[11] The four scenarios are more or less congruent with the 2000 SRES-scenarios for the IPCC: A1, A2, B1 and B2 respectively (see http://www.mnp.nl/image/ and section 4.2.4).

including from a halving of infant mortality over the first half of the century. The literacy rate keeps going up, driven by income-related government expenditures (the sub-model on education is still under construction and has no dynamic role to play). The projected changes suggest that India will have a relatively young population for at least a few more decades – ageing issues not becoming a major concern before 2030 (Annex D and *Figure 13*).

*Economy*. The economic module represents supply, demand and trade in each of five economic sectors: agriculture, primary energy, raw materials, manufacturing and services. Education and health levels do influence factor productivity and, hence, economic performance. Investments in education and health come from government expenditures, such as other expenditure destinations (military, social, among others).

With the exception of the Security First scenario, GDP-growth rate shows the typical humped curve: accelerating from the current 5%/year to 8%/year by 2030, after which it declines to 2–3%/year by the end of the century – at which time India will have become another and more crowded Europe after a century of modernization. In terms of market prices, around 2060–2070 the average Indian individual will have an income comparable to that of the present-day European (1995 USD/cap); this will occur 10 years earlier if PPP corrections are used [12]. These income growth expectations are in line with recent official projections (compare Section 4.2.2). Yet, such income levels combined with the prevailing population density lead to an economic activity density (in USD/year/km$^2$) that is 17% higher *for the whole of India* than the present value for the Netherlands, which is one of the most densely inhabited country in the world – and 12-fold higher than the present value for the USA. This implies huge changes over the next 50 years (= two generations). Given the high urbanization rate by 2050, the picture that develops is one of a world of huge densities of people and activity in megalopolis regions.

To realize such an economic growth, the IFs model allows for the investigation of several macro-economic variables:

- The investment rate remains in the range of 22–25% of GDP for most of the century, with the exception of the low-tech low-growth regionalist Security First scenarios with a drop to 20% towards 2040;
- This high growth rate allows a smooth but significant increase of the tax rate towards 'European welfare state' levels of 35–40% by 2100, while at the same time limiting the government deficit to less than the (present) 4% and even bringing it to nil after 2040 (*Figure 23*);
- Equally important is that income inequality is assumed to diminish – to the extent that MDG-1 *Eradicate extreme poverty and hunger* comes close to realization if measured as the proportion of population under USD 1/day and of underweight children under age 5; only in the Security First scenario does the 2015 targets remain out of reach;
- Of course, this presumes that an effective government is able to collect increasing taxes and to spend them effectively in such areas as public health and primary, secondary and

[12] PPPs (or INR) are calculated and used according to the assumption that the difference to the leading country determines its value.

tertiary education. From the worldview scenario perspective (compare *Figure 10*), this only has plausibility if India is able to maintain the middle road between extreme and market-driven globalization on the one hand and extreme and impoverishing regionalism on the other.

In all scenarios, economic growth coincides with further integration in the world economy – although much more so in the globalizing high-tech Market First world than in the Security First (50% of GDP against 20% of GDP, respectively, exported in 2100). In addition, the physical support system has to sustain such developments – which is the topic of the next sections.

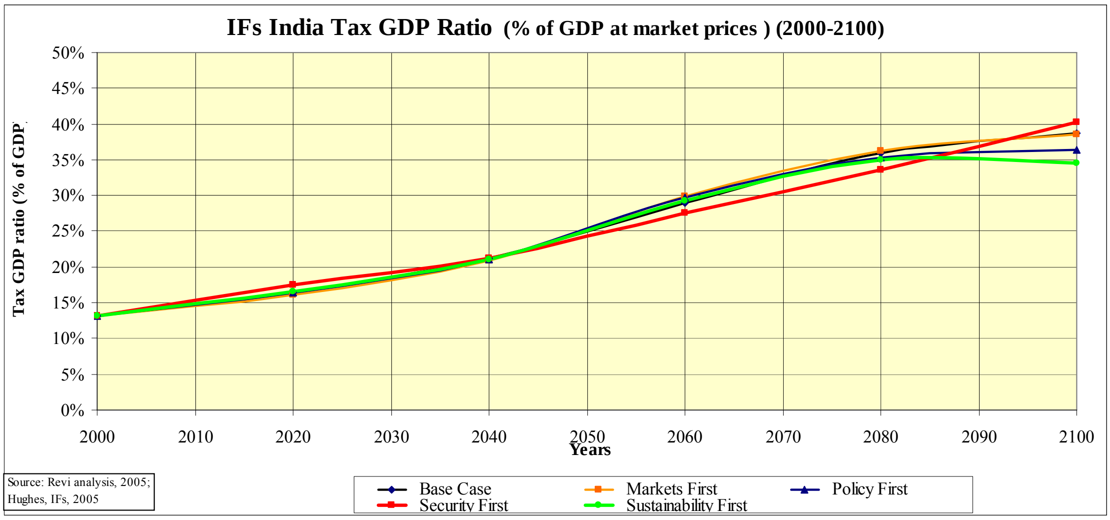



*Figure 23 Tax rate as a percentage of GDP in the IF-model runs for the Base case and the four IPCC-SRES scenarios.*

*Food.* Agricultural production is determined by way of a production function in labour and capital and with diminishing returns to yield-improving investments. Income and technology have a positive effect on yields, whereas rising $CO_2$-concentrations affect yields adversely. Agricultural demand is divided into crop and meat/fish, with three components in crop demand: food, feed (for livestock) and industrial. The primary determinants of food demand are the size of the population and the consumption level per capita. Prices affect food demand through elasticities.

In the IFs simulations there is a continuing though slowing down of the increase in yields in all but the Security First scenario. India remains self-sufficient in food – although in 2000, agricultural production is almost twice the agricultural demand in the model, and agricultural imports increase greatly, a development which needs to be clarified. The assumptions behind the simulations are that intensification of agriculture can continue unabated in the form of multicropping schemes, more and/or more efficient fertilizer use, more irrigated land, among others. If capital, energy and water are available at the necessary rates, such a path may well be possible. However, all of these developments will run into rising marginal costs if population and industrial and service sector activities keep growing. One indication of stress is the projected decline in forested area: in the 'non-green' scenarios, forested area will decrease by 50% before it starts recovering in the second half of the century. It is unclear how a significant change in diet would affect the outcome.

*Energy*. The IFs energy sub-model is quite basic. Demand for energy grows concurrently with an increasing population and GDP – but at declining energy intensity. Energy is produced in a capital-stock with a Capital-Output Ratio (COR). Reserve depletion has a negative effect on capital productivity.

The IFs simulation sketches a rosy future for the energy situation in India in the 21st century. Despite an almost tenfold decrease in the energy intensity (GJ/USD), the increase in both population and economic activity boosts demand for commercial energy carriers from 16 EJ/year in 2000 to 270 EJ/year in 2100 [13]. The spread in this last number is 160–340 EJ/year, which can be compared with the 2000 world energy use, which is in the order of 400 EJ/year. This growth in energy use is rather high in comparison with, for example, the TIMER-based OECD scenario (*Figure 19*). For the coming decades, however, it implies the same as most other projections: commercial energy use in India will become over the next 20–30 years similar to the present use in Europe (68.5 EJ/year in EU-25 in 2005). The supply of this energy is supposed for the largest part to be from imports (oil, gas); indigenous production (coal, nuclear, renewables) is actually declining in all scenarios. The price of energy rises until 2050, after which it declines to between one quarter and one third of the 2000 level.

In addition to the aspect of global fuel trade and depletion, the projected energy future of India has another important consequence: carbon emissions. In the IFs scenarios, the carbon emissions increase significantly for the next few decades – three- to five-fold its present level by 2040. This also is roughly in line with the recent Planning Commission (2005) estimate. Thereafter, it starts to decline rapidly as the non-carbon renewable sources take off. This mitigates the consequences in the form of climate change, which in turn may limit disastrous consequences for agriculture and the energy and water systems. Whether this is realistic is to be discussed.

However, the results obtained to date with the IFs model are inconsistent. It seems that one has to understand a large role for non-hydro, non-nuclear renewable energy sources – they already provide 50% of the supply by 2035. It is unclear how this could happen. Whatever the reasons and interpretations, there are some large differences with the TIMER-model-based simulations, which is being explored in more detail (Annex G).

[13] The – not insignificant – energy from renewable sources, such as biomass and hydropower, is apparently not considered.

**Air pollution and forest clearance endanger Indian monsoon**

Increasing air pollution and forest conversion in South Asia could lead to a failure of the Indian summer monsoon. This has been shown by researchers at the Potsdam Institute for Climate Impact Research (PIK) in a study exploring the stability of the Indian monsoon. The results of the study appeared in the current issue of "Geophysical Research Letters" (Zickfeld, K., B. Knopf, V. Petoukhov, and H. J. Schellnhuber (2005) Is the Indian summer monsoon stable against global change?, Geophysical Research Letters, 32, L15707, doi: 10.1029/2005GL022771).

The recurrent monsoon rains have a profound impact on the lives of people in India. A weak summer monsoon is frequently accompanied by poor harvests and food shortages among the rural population, which constitutes two-thirds of India's total population. Monsoon precipitation that is stronger than usual can similarly have devastating consequences, as the catastrophic rainfalls of july 2005 in Mumbai (Bombay) have demonstrated.

In the current PIK study, researchers discovered a mechanism which could lead to a failure of the Indian summer monsoon: increasing air pollution with airborne particles ("aerosols") over India - caused by fires and the consumption of fossil fuels as well as forest clearance – could lead to a regional increase of the Earth's brightness ("planetary albedo"), resulting in less sunlight reaching the surface and causing the temperature over land to decrease. In such a case, the supply of moist air which feeds the monsoon rains ceases and precipitation decreases dramatically.

The likelihood of such a breakdown of the Indian summer monsoon cannot be inferred from the study. For this, analyses will be needed which consider realistic projections (so-called "scenarios") of the air pollution as well as of land-use change in South Asia. Also, a further effect would have to be considered: rising concentrations of GHGs. The latter have an opposite effect on the summer monsoon: more GHGs in the atmosphere lead to a temperature increase over land and thus to stronger precipitation. At present it is still not possible to determine which one of these two effects will ultimately dominate.

The PIK was founded in 1992 and employs about 110 scientists. Its research on climate change, climate impacts and sustainable development is of international renown. PIK is a member of the Leibniz Association.

*MDG in IFs.* One of the interesting features of the IFs-model is that it is able to relate country projections to targets such as the MDG. India’s National Development Goals map fairly closely to the MDGs, while being more ambitious than these in many other areas. Nevertheless, especially in the areas of poverty and human development, the IFs-model provides an important means of tracking progress and examining the sensitivity of overall development and sector-specific policies. For the longer term issues, there is the potential impact of climate change, part of which seems unavoidable now and has to be dealt with by anticipation and adaptation. The IFs-model may be too aggregate and/or optimistic here.

## 5.3 Key issues in the IFs implementation for India

Our exploration of the projections for India with the IFs-model are meant to find out (1) which improvements have to be made in order to bring the model simulation closer to the Indian reality, and (2) the usefulness and possible extensions if the IFs framework as an overarching platform to link the various Global Change models at MNP [14]. Our conclusion is that the IFs-model provides a good point of departure for integrated assessment modelling at the regional and country level. However, the sheer size of India makes it necessary to disaggregate to state and, in certain aspects, district level in order to capture important interactions between the growth in human numbers and activities on the one hand and the potential of the biogeographical resource base to sustain human-induced pressures. The basic capability of breaking individual countries like India into states or provinces has been created and will be enhanced over time. For example, some fundamental economic and demographic data are being added for all of the states and union territories of India, making it possible for those states to be treated individually or grouped into regions of the country for model runs and analysis. Full treatment of such states or regions will depend on both the availability of additional data and extended modelling of their linkages and interactions.

In the MNP-GISMO context, this may include initial focus:

- A joint exercise to simulate demographic and economic development processes for one or two states, taking into account the specifics of fertility and mortality patterns, land-cover and land-use features, economic structure and energy and water resources;
- A confrontation of simulation results for India, calculated with various models for the population-economy-environment dynamics until 2050 in order to calibrate and possibly validate the role of important phenomena such as son preference, the food and (ground)water innovation and depletion dynamics, the role of the (international) (ICT) service sector and the role of infrastructure investments (health, education, transport).

On a practical note, the use of SAM and financial sheets in agreement with World Bank conventions is a positive feature of the IFs model. It would be interesting to redo the India 2050 simulations with a more empirically solid database on I-O- and SAM-matrices. Based on the I-O-matrices for India, it is possible to construct the datasets required for the IFs model for the historical period from 1978 onwards. *Figure 24* shows the shift in final demand between 1978 and 1998 in the categories used in the IFs model (compare *Figure 4*). The I-O-matrix technical coefficients are also available for India in 1978–1979, 1983–1984, 1989–1990, 1993–1994 and 1998–1999 (compare *Figure 7*; Annex D). It can be seen that the change in the technical coefficients, although not spectacular, has been significant in parts of the economy. One of the obvious tasks is to run the IFs-model with these historical I-O data (see Annex E for the sectoral aggregation).

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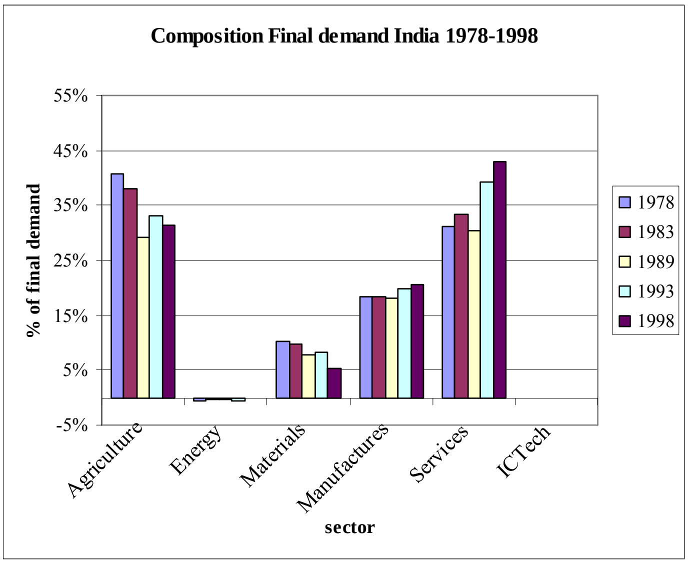
[14] This evaluation was made in december 2005. Since mid-2006 a number of extensions in the indicated directions have been made in the IFs-model, partly in the context of a model implementation at the India state level.




In the remainder of this section, we present a list of priority issues to be dealt with in the case of a follow-up project. Most of these are comments on the outcome from the perspective of past and present trends and an appraisal of political and institutional plausibility.

*Figure 24 Change in the composition of final demand in the official economy in India 1978-1998 at the aggregation level of the IFs model.*

## 5.3.1 Population

a. Expanding the household set (rural landless, rural small and marginal farmer, rural large farmer, urban poor, urban middle class and urban rich) may be essential to understand demographic and socio-economic dynamics in India;
b. Urbanization growth rates in India are overstated in the early 21st century; Indian urban growth is constrained by settlement structure, employment opportunities, relative costs of living in urban and rural areas; it should also be linked to migration dynamics;
c. The projected high increase in life expectancy may be unrealistic due to population momentum; for the population on average, it would mean significant early changes in nutrition, health investments and the health care system and reducing gender asymmetry;
d. Infant Mortality Rate (IMR) reduction is a key MDG that may not be achieved because of the challenges posed by water and sanitation needs, universal immunization, effective nutrition interventions and a revamp of the public health system; the IFs (and PHOENIX) simulations may be too optimistic here;
e. The literacy MDG may be achieved faster if the Fundamental Right to Universalization of Elementary Education is implemented by means of a massive increase in investments resulting in school quality improvement together with massive social mobilization in terms of adult literacy; to assess its feasibility, the roll-over of new literates into the secondary and higher education system needs to be examined, which can be built into both the PHOENIX and the IFs model.

## 5.3.2 Economy

a. Many IFs projections are driven by (changes in) GDP, with income driving the larger part of the (sub)system dynamics; the economic scenario approach allows a broad band of pathways, but an explicit link with the various non-income determined policy levers should be added to explore less income-driven changes;

b. A large part - also in the decades to come - of Indian human activity may be outside the national accounts (informal/illegal) - for example, in rural households and in the urban non-skilled service sector; ways to incorporate these into the model should be explored;
c. In connection with the previous points, it would be interesting to see how different assumptions on (for example, the PPP conversion) would affect outcomes; PPP coefficients could imply a less skewed world economy but is this with or without structural change in the global governance system?
d. The IFs projections appear to assume a smooth transition towards a European-style welfare state with a growing, large tax base – is this expansion of the state system feasible in an environment that is dominated by free trade and competitive globalization? Is it realistic to assume that all state systems are gravitating towards a current account surplus, as in the IFs model?
e. The long-range investment to GDP ratio in India increases to 22-25% in the model simulation, while income rises sharply – is this realistic or should one expect a decline in the historically high Asian savings rates? A related question is whether the presumed high income growth can occur for decades concurrently with declining inequality in income and wealth distribution;
f. The large volume of trade assumed in the model may be a causal factor rather than an outcome. How will export to GDP in India surpass 40 %– how does a breakdown by sector look like, is the export service-sector driven and is it delinked from the 'real' economy?

### 5.3.3 Food-Energy-Water

a. The global GDP estimates are driven by long-range 20th century growth trends – but without feedbacks from limitations related to energy and water availability/access, deforestation, soil and groundwater depletion and climate change. More research is needed into the possibility and shape of overshoot-and-collapse modes of the system, looking at key feedbacks such as food and environmental quality to mortality, land degradation and food, water and food and energy and climate change;
b. Because of such feedbacks, the projected mean long-run GDP-growth rate of 3%/year may be difficult to sustain; it can be expected that such feedbacks work their way through aspects of the governance system (corruption, informal economy), productivity (health, education, transport and communication networks), migration and poverty (local/regional marginalization), among others (see, for example, Shukla *et al.* 2003;
c. Carbon emissions peak in mid-century in all IFs scenarios, with massive decline in per capita and per unit GDP intensities. Given the simple way in which the energy transition is modelled, this may be a rather unreliable outlook;
d. Forest area decline in mid-century, as occurs in some IFs scenarios, seems probable. It is unclear, however, what drives the reforestation in the second half of the century: bio-fuels?
e. Water availability is probably the first 'limit' to be reached in India. This may result in serious livelihood and food constraints, in particular in locations with large climate variability. There is apparently no feedback from freshwater use and agricultural yield and no disaggregation of surface and groundwater. This makes it hard to relate the outcome to the political situation 'on the ground'.

# Conclusion

In this report it is concluded that India will experience an extremely dynamic period over the next decades. Fuelled by the ambitions and skills of an extremely large, young and educated population, it will aspire for a more prominent place in the globalizing world of the 21st century. In the process, it will be confronted with large opportunities. They can be seen everywhere in present-day India, often in the form of leapfrogging, as with mobile phones, glass-fibre cable Internet and low-cost air carriers. There are also threats. Foremost among these are the large and rising income inequalities, which may jeopardize the stability in the world's largest democracy; however, other factors not to be ignored are the political and financial risks of a heavy and rapidly growing import of oil and gas, the enormous challenge to provide health, education and transport infrastructure sufficiently fast and of sufficient quality and accessibility and the deterioration of the ecosystem service base which may, in combination with climate change, threaten the adequate provision of food and water.

More (model-based) research is needed and this should be focused upon the nature of the (aspired) economic growth, the required size and nature of investments in health, education and other (land, water, energy, transport) infrastructure and the potential feedbacks and impacts from the environment. Only in this way will the tools become available that are needed to meaningful assess – on a long-term basis – the developments in this increasingly important country on the world stage. The most urgent extension of existing work may be the desaggregation of existing models to the state level with the aim of dealing more adequately with the heterogeneity of important dynamic mechanisms and their interlinkages.

More specifically, there is a need for the construction of system dynamics models for particular subsystems and empirical and theoretical research into the connections. In models such as PHOENIX and IFs, the ways in which economic growth in general and improvements in health and education in particular interact with population growth mechanisms are of paramount importance in India. Another issue of great importance is whether the food supply system can expand to meet growing demand and changing diet within the constraints of water and soil availability. For both areas, the role of technological innovations and governance structures are key factors which have to be worked out in more detail on the basis of the scenario methodology.

The present study confirms that India provides a good testing area for long-term modelling of sustainable development options in low-income regions in the world. A large, growing and rather reliable database is available. The subcontinent has enough variety in biogeography and socio-economic development stage to cover a wide array of development pathways. And, last but not least, its fast economic growth is making it rapidly one of the key players in the world political arena. Consequently, it is important for the world community that India develops a solid instrument for the exploration of a sustainable future and the pitfalls on the road towards it.

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# Annex A Project proposal

*The original work packages.* The aim was to construct a number of modelling frameworks and model interfaces, as outlined below. This only succeeded partly, as there was a shortage of time and a lack of consensus on the road to follow. The project proposal hoped to achieve (January 2005):

1. Extension of the PHOENIX-model to include the effects of health and education expenditures; Excel spreadsheet with all Phoenix in- and output variables to be filled in with India data 1971-2002;
2. Extension of the TIMER-model to include a number of specific characters in terms of traditional biofuel use, among others; Excel spreadsheet with all TIMER in- and output variables to be filled in with India data 1971–2002;
3. Adjustment of the IMAGE-TES-model and, if possible, the WaterGap-model in order to make comparisons with India data; minor model extensions if required in dealing with a less developed region; Excel spreadsheet with the important TES in- and output variables to be filled in with India data 1971–2002;
4. Construction of an input-output framework, based on existing models (such as IFs, T21 and others); developing an explicit macro-economic dynamic context to explore the requirements needed for the realization of certain policy objectives; I-O data collection for India;
5. Use of the linked set of models to explore one or two possible futures of how India might develop according to social, economic and environmental indicators and which opportunities and risks are involved in each strategy.

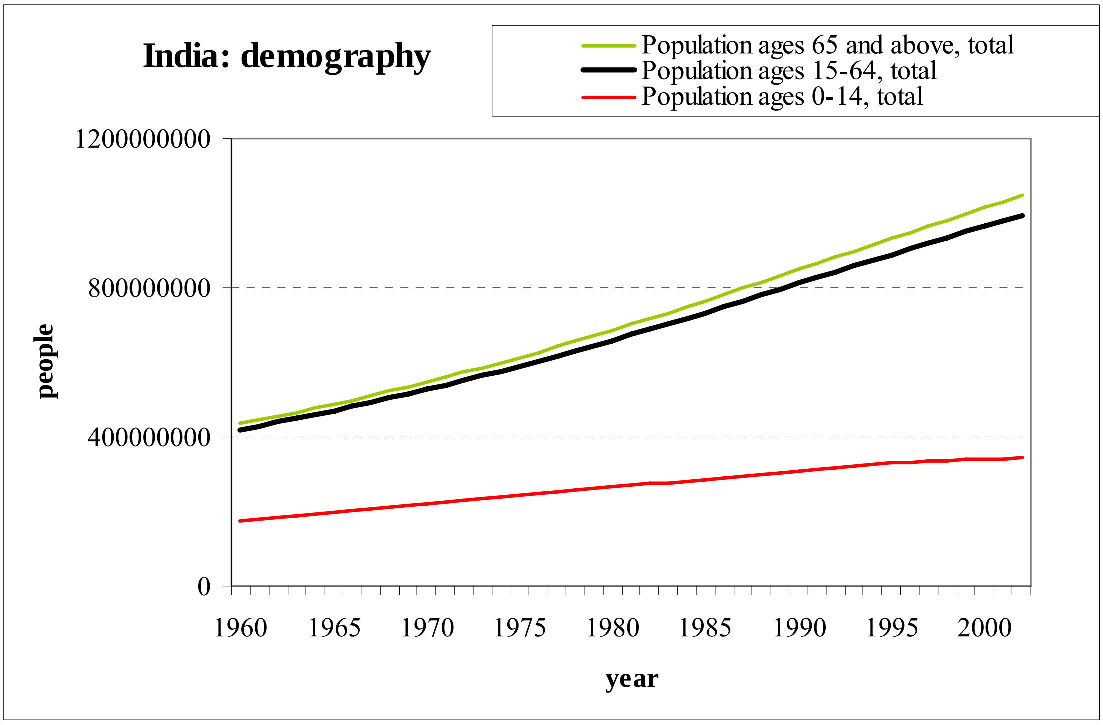
# Annex B Acronyms

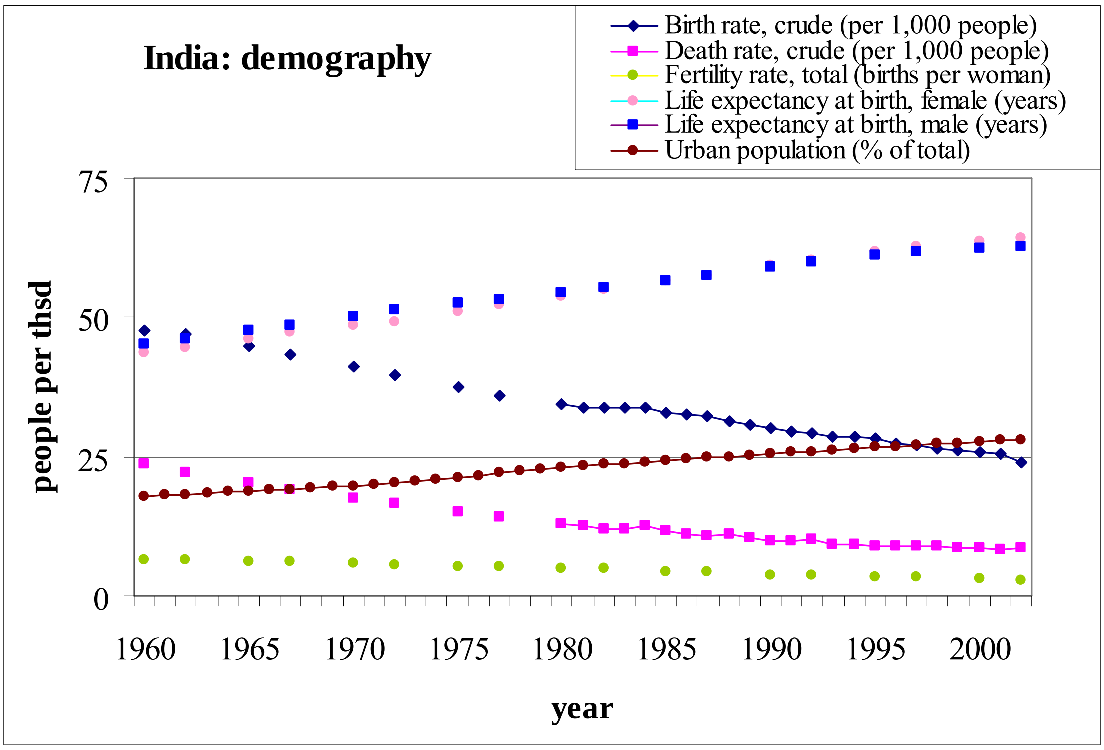
| | |
|---|---|
| CNG | Compressed Natural Gas |
| GEO | Global Environmental Outlook |
| IFs | International Futures |
| IMAGE | Integrated Model to Assess the Global Environment |
| IMF | International Monetary Fund |
| IMR | Infant Mortality Rate |
| KMD | Kliaamt en Mondiale Duurzaamheid |
| MDG | Millennium Development Goals |
| MNP | Milieu- en Natuur planbureau (Netherlands Environmental Assessment Agency) |
| PPP | Purchasing Power Parity |
| SAM | Social Accounting Matrix |
| SNA | System of National Accounts |
| TERI | The Energy and Resource Institute (formerly Tata Energy Research Institute) |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| WHO | World Health Organization |

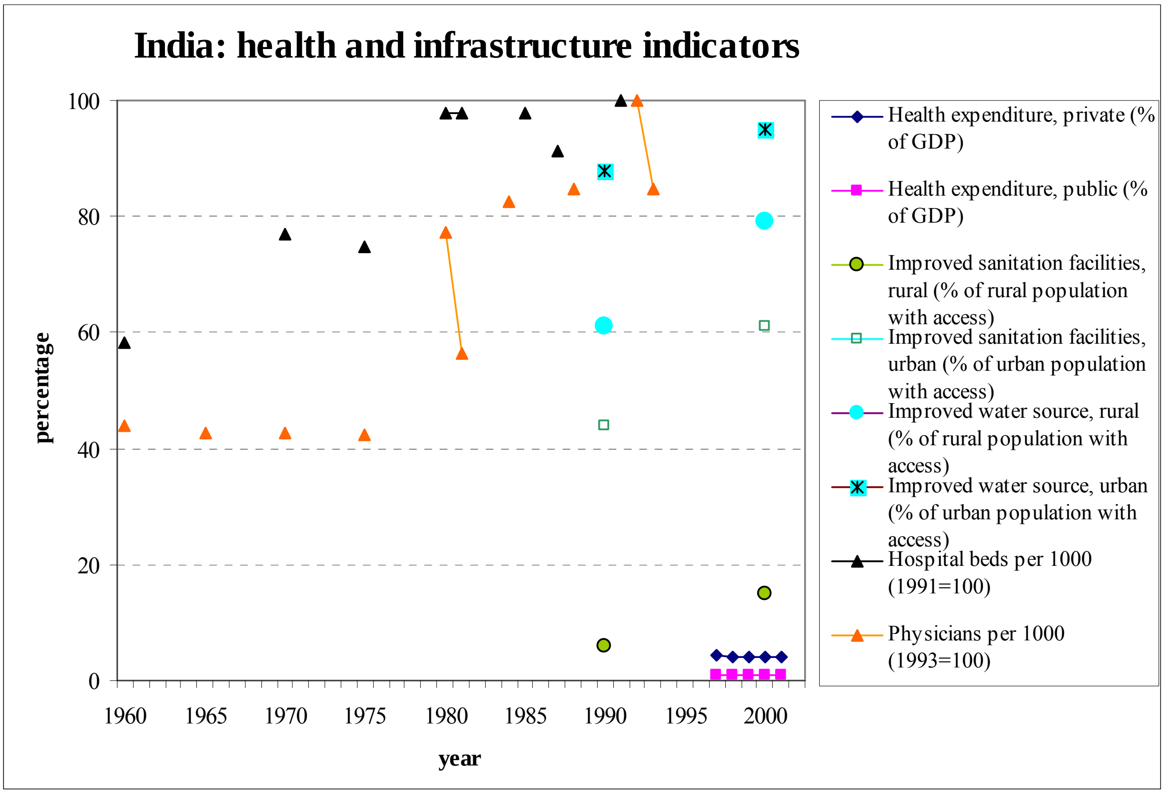
# Annex C India 1950–2000 trends

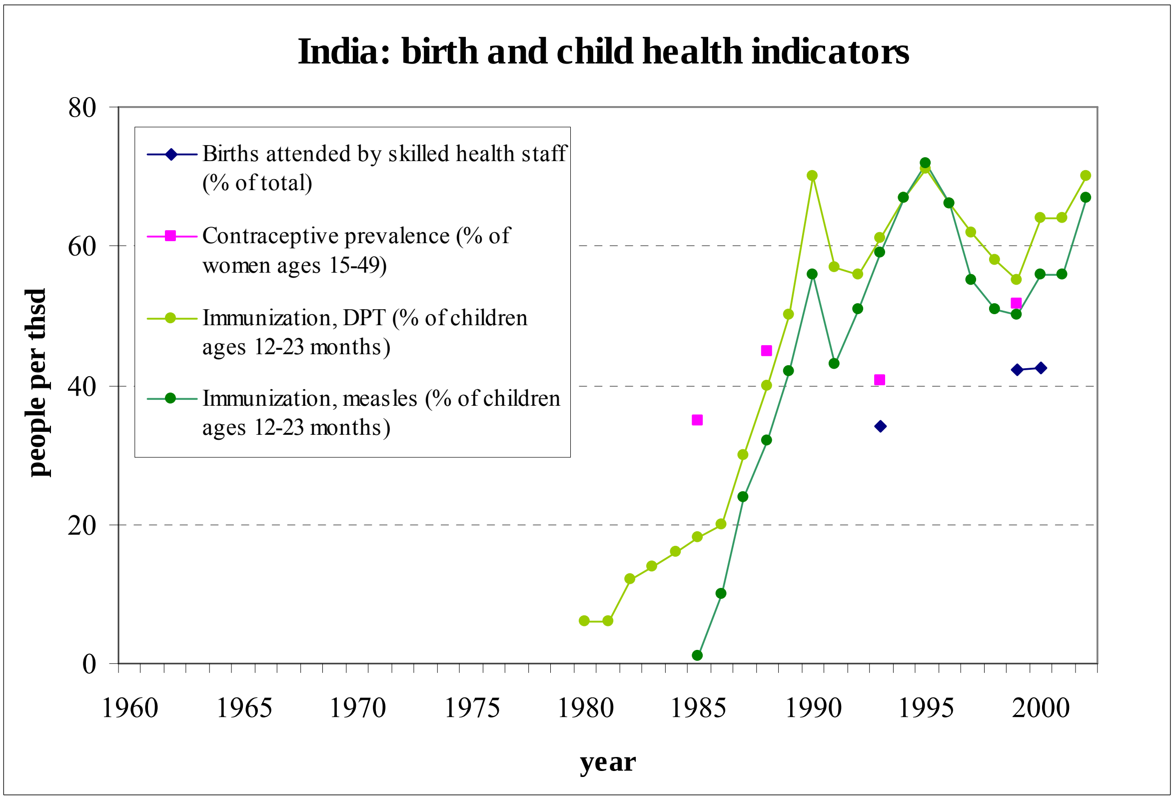
**(Sources: WDI, IndiaStat, G.K. Bhat 2006)**

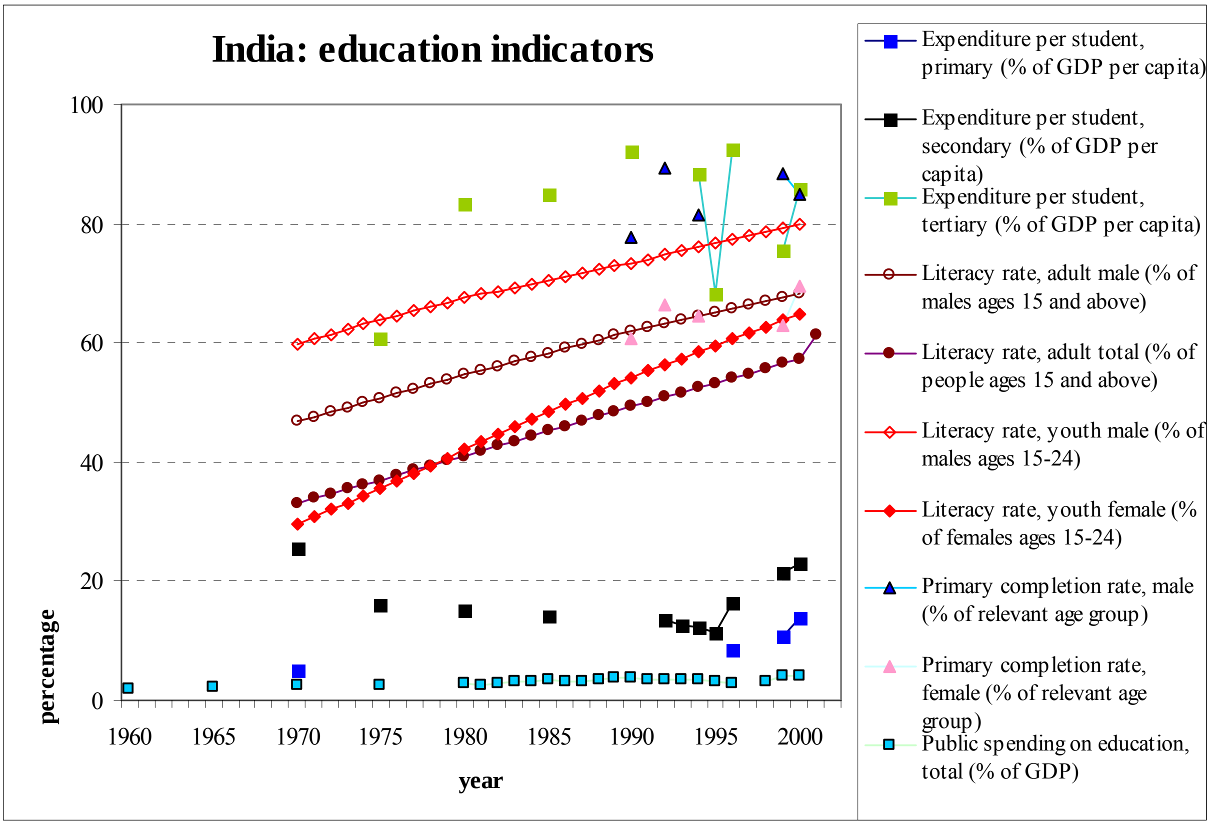
*Population*

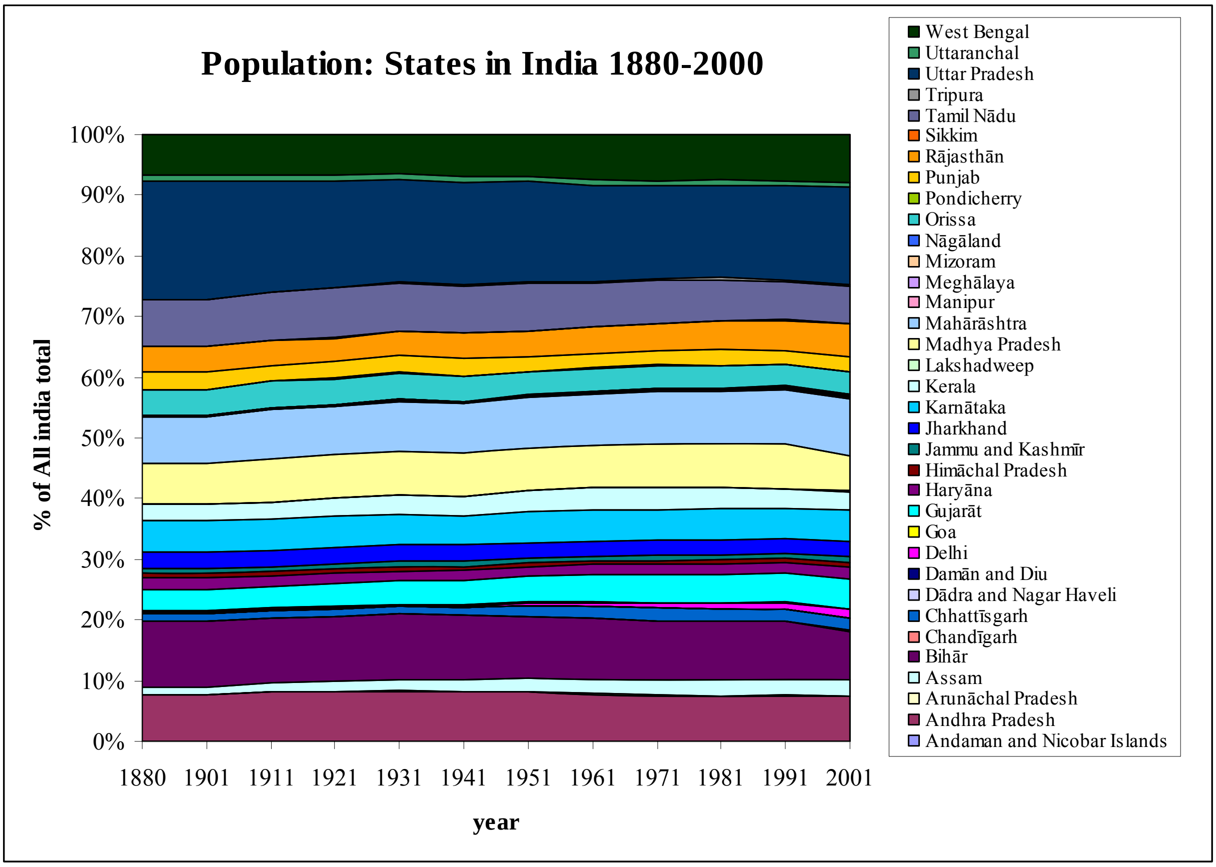


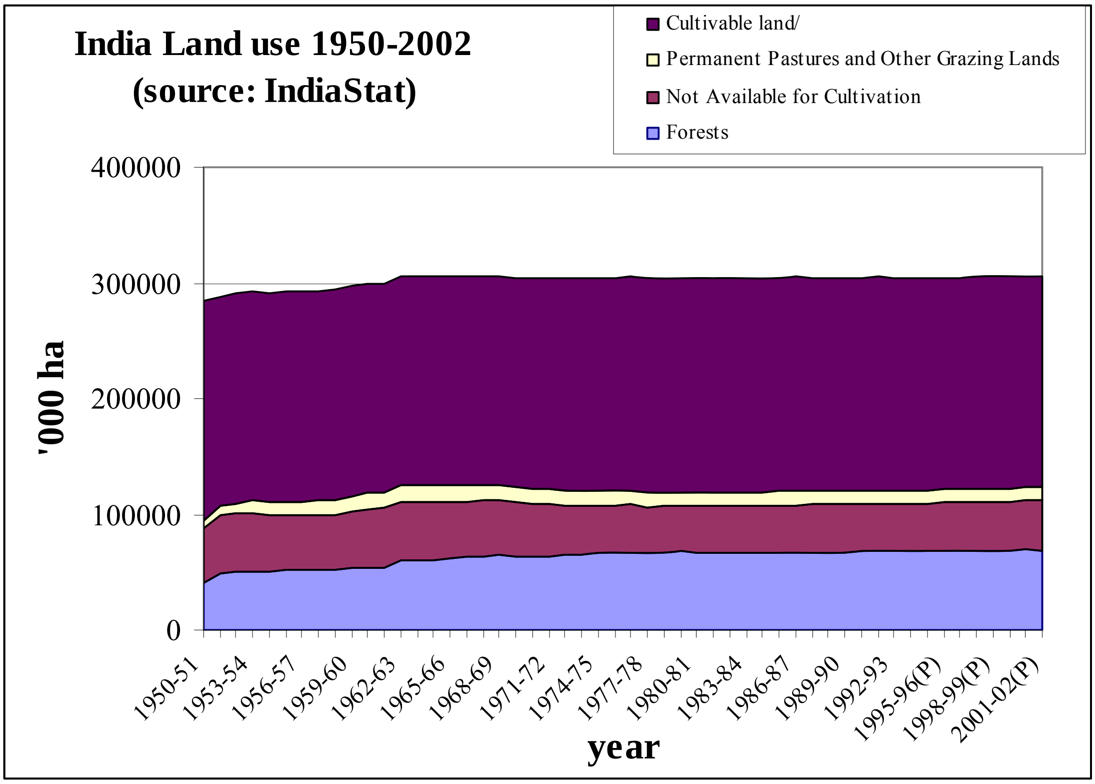

India: health and infrastructure indicators
percentage
year
Health expenditure, private (% of GDP)
Health expenditure, public (% of GDP)
Improved sanitation facilities, rural (% of rural population with access)
Improved sanitation facilities, urban (% of urban population with access)
Improved water source, rural (% of rural population with access)
Improved water source, urban (% of urban population with access)
Hospital beds per 1000 (1991=100)
Physicians per 1000 (1993=100)

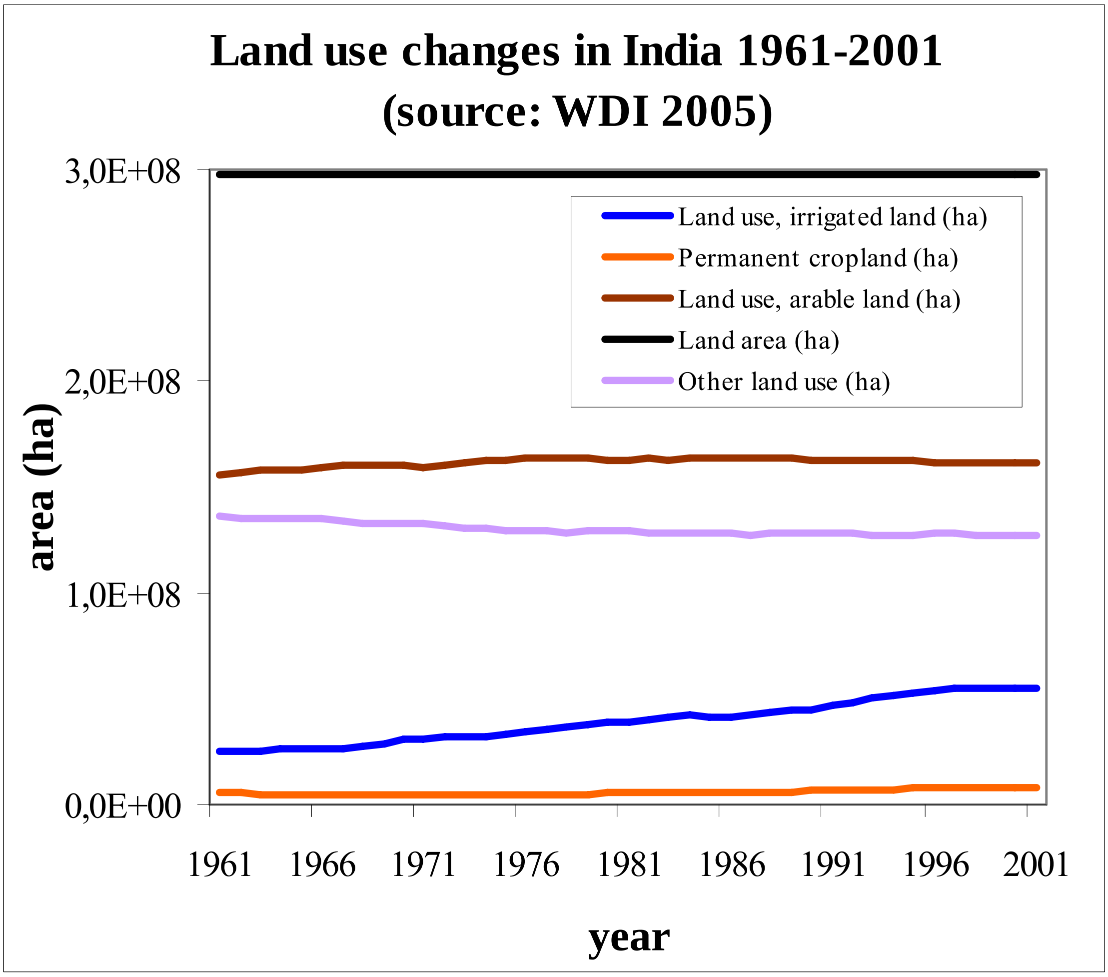

India: birth and child health indicators
people per thsd
year
Births attended by skilled health staff (% of total)
Contraceptive prevalence (% of women ages 15-49)
Immunization, DPT (% of children ages 12-23 months)
Immunization, measles (% of children ages 12-23 months)

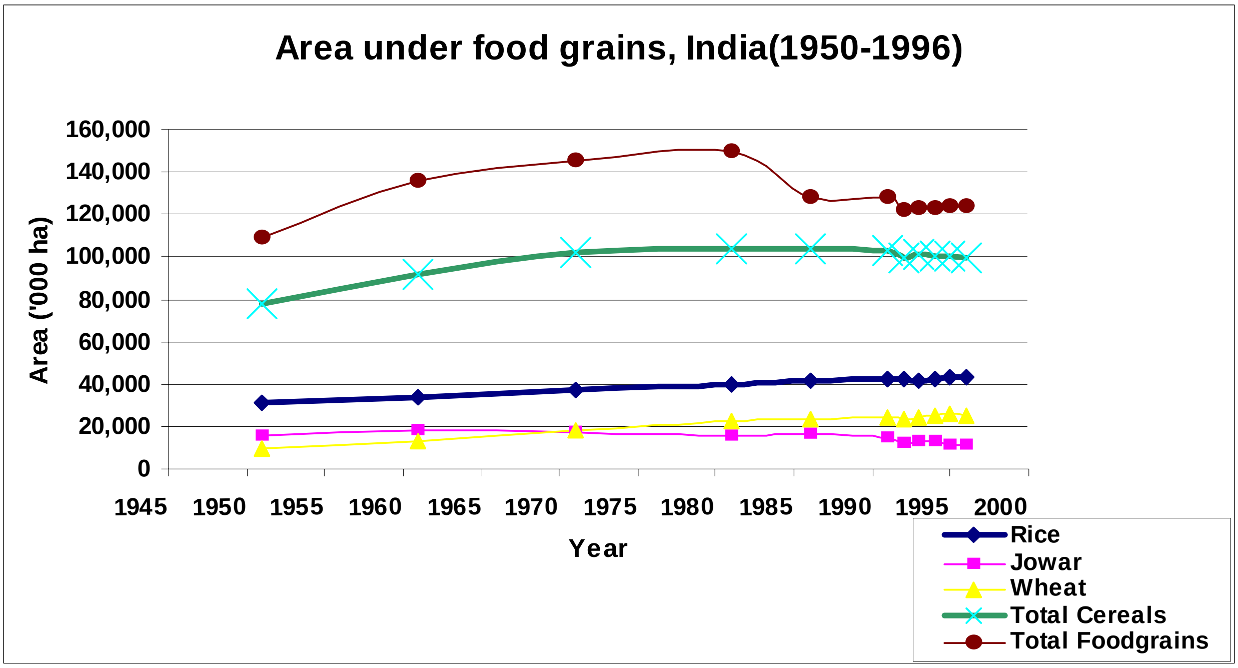

India: education indicators
100
80
60
40
20
0
percentage
1960
1965
1970
1975
1980
1985
1990
1995
2000
year
Expenditure per student, primary (% of GDP per capita)
Expenditure per student, secondary (% of GDP per capita)
Expenditure per student, tertiary (% of GDP per capita)
Literacy rate, adult male (% of males ages 15 and above)
Literacy rate, adult total (% of people ages 15 and above)
Literacy rate, youth male (% of males ages 15-24)
Literacy rate, youth female (% of females ages 15-24)
Primary completion rate, male (% of relevant age group)
Primary completion rate, female (% of relevant age group)
Public spending on education, total (% of GDP)

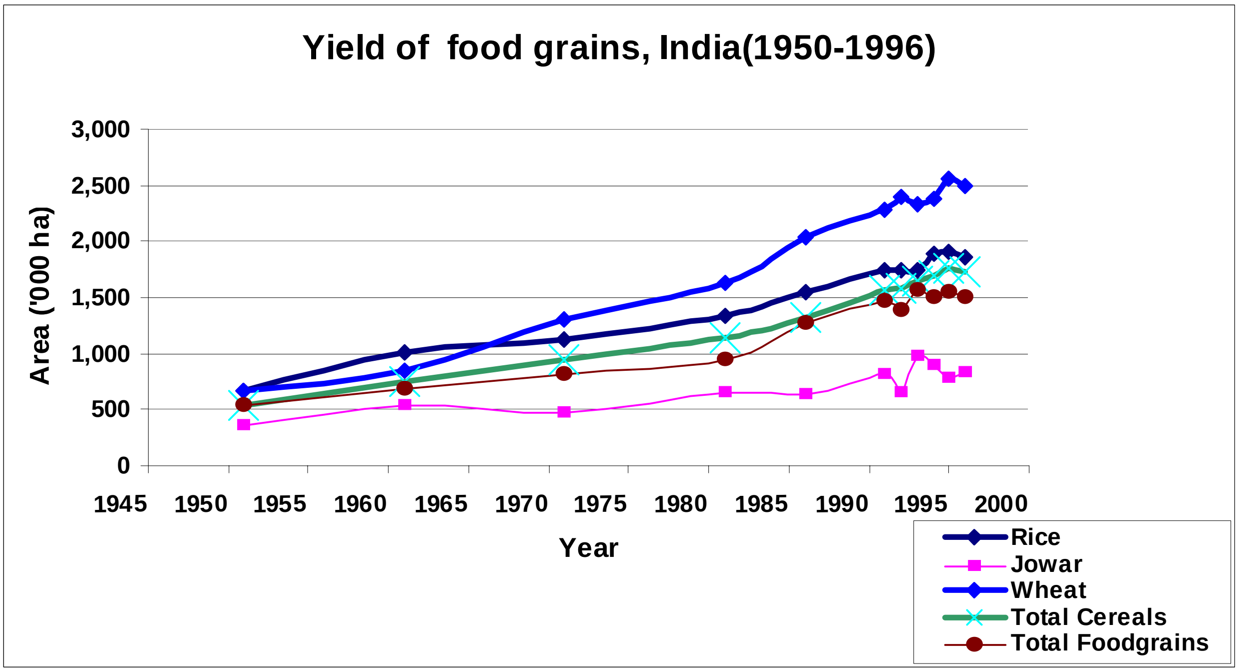

Population: States in India 1880-2000
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of All india total
1880
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
year
West Bengal
Uttaranchal
Uttar Pradesh
Tripura
Tamil Nādu
Sikkim
Rājasthān
Punjab
Pondicherry
Orissa
Nāgāland
Mizoram
Meghālaya
Manipur
Mahārāshtra
Madhya Pradesh
Lakshadweep
Kerala
Karnātaka
Jharkhand
Jammu and Kashmīr
Himāchal Pradesh
Haryāna
Gujarāt
Goa
Delhi
Damān and Diu
Dādra and Nagar Haveli
Chhattīsgarh
Chandīgarh
Bihār
Assam
Arunāchal Pradesh
Andhra Pradesh
Andaman and Nicobar Islands

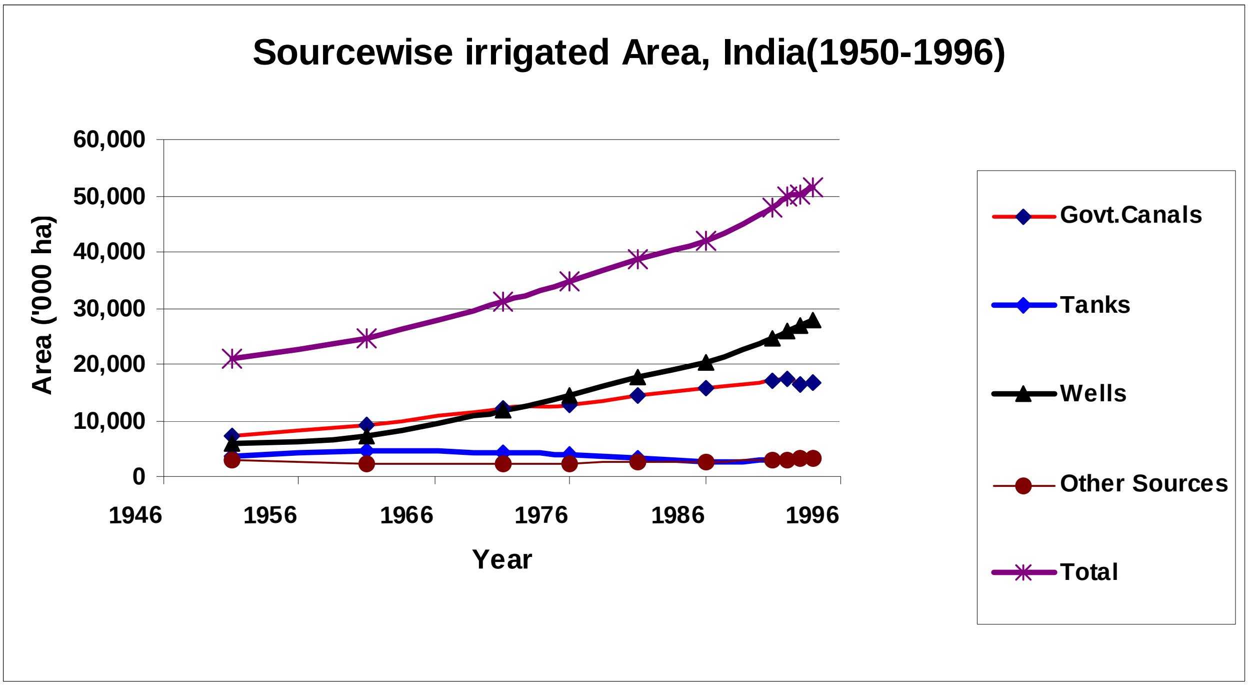
***Food***

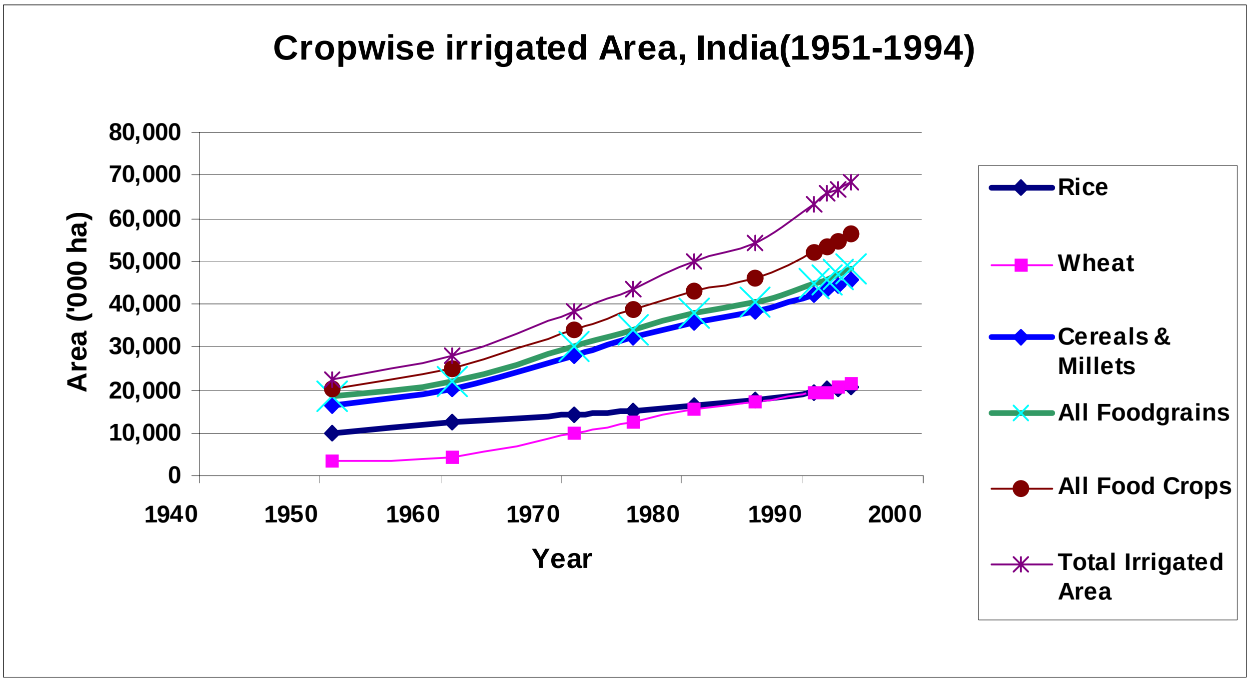

India Land use 1950-2002
(source: IndiaStat)
Cultivable land/
Permanent Pastures and Other Grazing Lands
Not Available for Cultivation
Forests
'000 ha
400000
300000
200000
100000
0
1950-51
1953-54
1956-57
1959-60
1962-63
1965-66
1968-69
1971-72
1974-75
1977-78
1980-81
1983-84
1986-87
1989-90
1992-93
1995-96(P)
1998-99(P)
2001-02(P)
year


Land use changes in India 1961-2001
(source: WDI 2005)
Land use, irrigated land (ha)
Permanent cropland (ha)
Land use, arable land (ha)
Land area (ha)
Other land use (ha)
area (ha)
3,0E+08
2,0E+08
1,0E+08
0,0E+00
1961
1966
1971
1976
1981
1986
1991
1996
2001
year

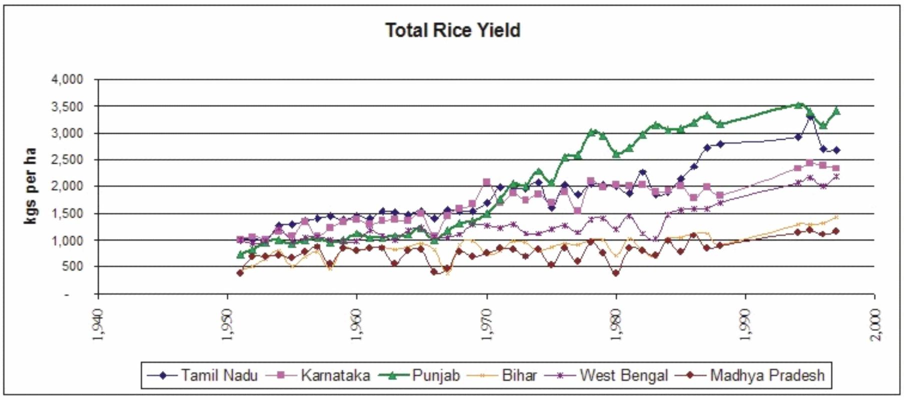

Area under food grains, India(1950-1996)
Area ('000 ha)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year
Rice
Jowar
Wheat
Total Cereals
Total Foodgrains


Yield of food grains, India(1950-1996)
Area ('000 ha)
3,000
2,500
2,000
1,500
1,000
500
0
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year
Rice
Jowar
Wheat
Total Cereals
Total Foodgrains

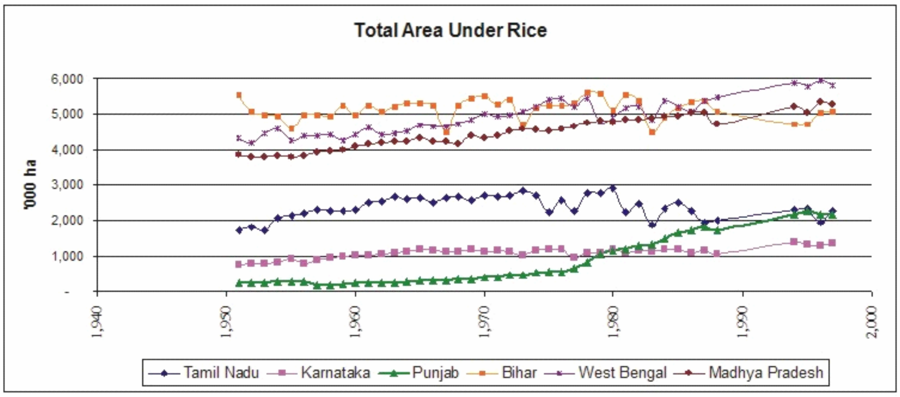

Sourcewise irrigated Area, India(1950-1996)
Area ('000 ha)
60,000
50,000
40,000
30,000
20,000
10,000
0
1946
1956
1966
1976
1986
1996
Year
Govt.Canals
Tanks
Wells
Other Sources
Total


Cropwise irrigated Area, India(1951-1994)
Area ('000 ha)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1940
1950
1960
1970
1980
1990
2000
Year
Rice
Wheat
Cereals & Millets
All Foodgrains
All Food Crops
Total Irrigated Area

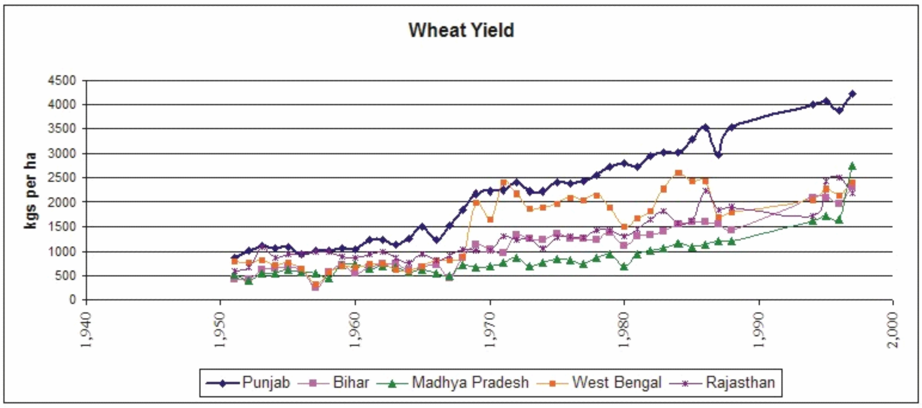
## TOTAL RICE YIELD



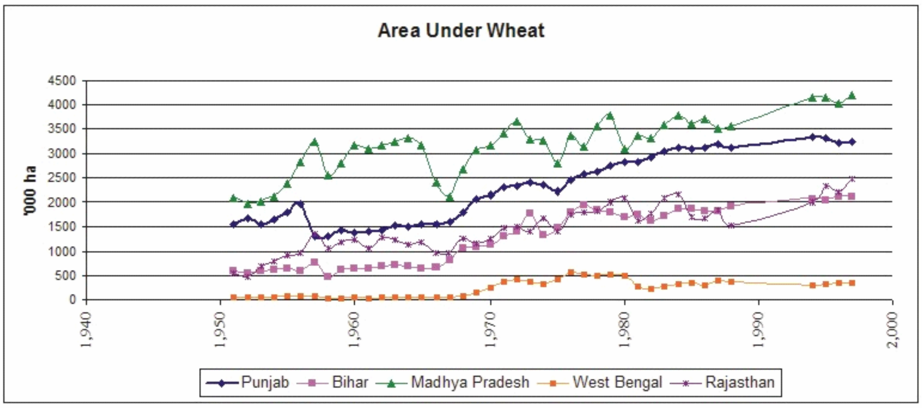

## TOTAL AREA UNDER RICE



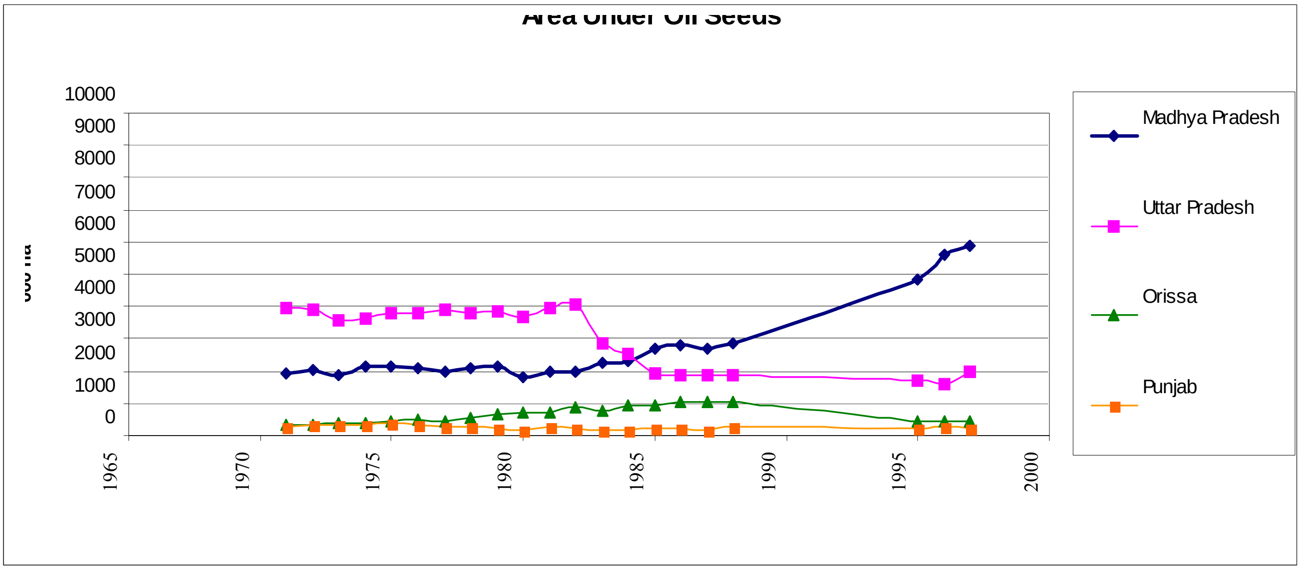

## TOTAL WHEAT YIELD



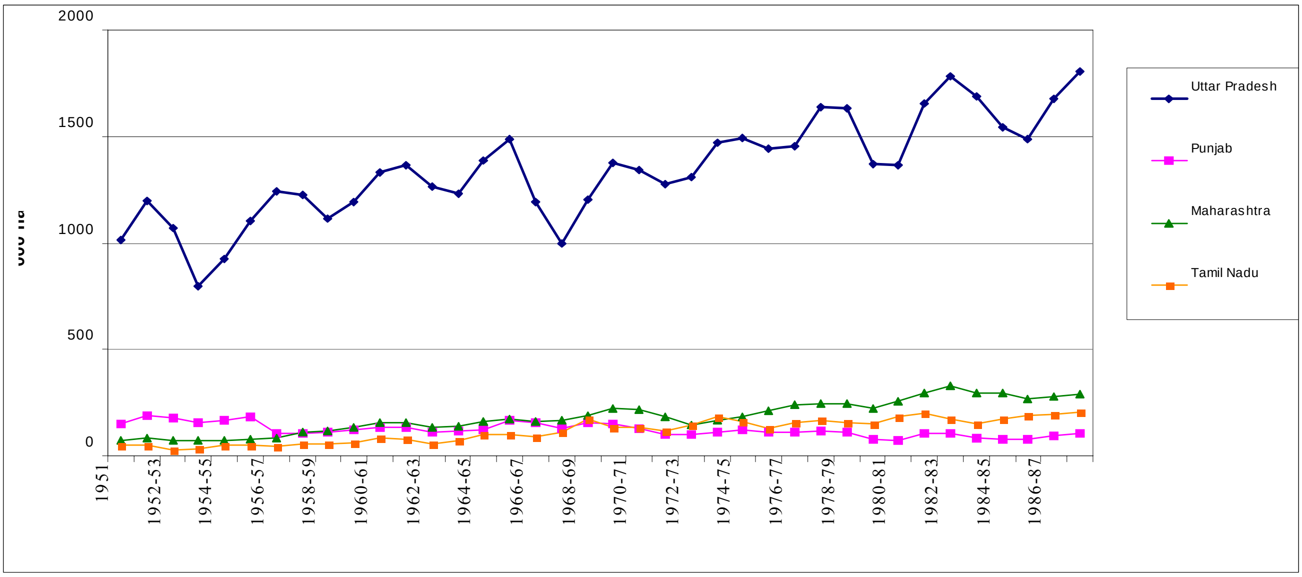

## TOTAL AREA UNDER WHEAT

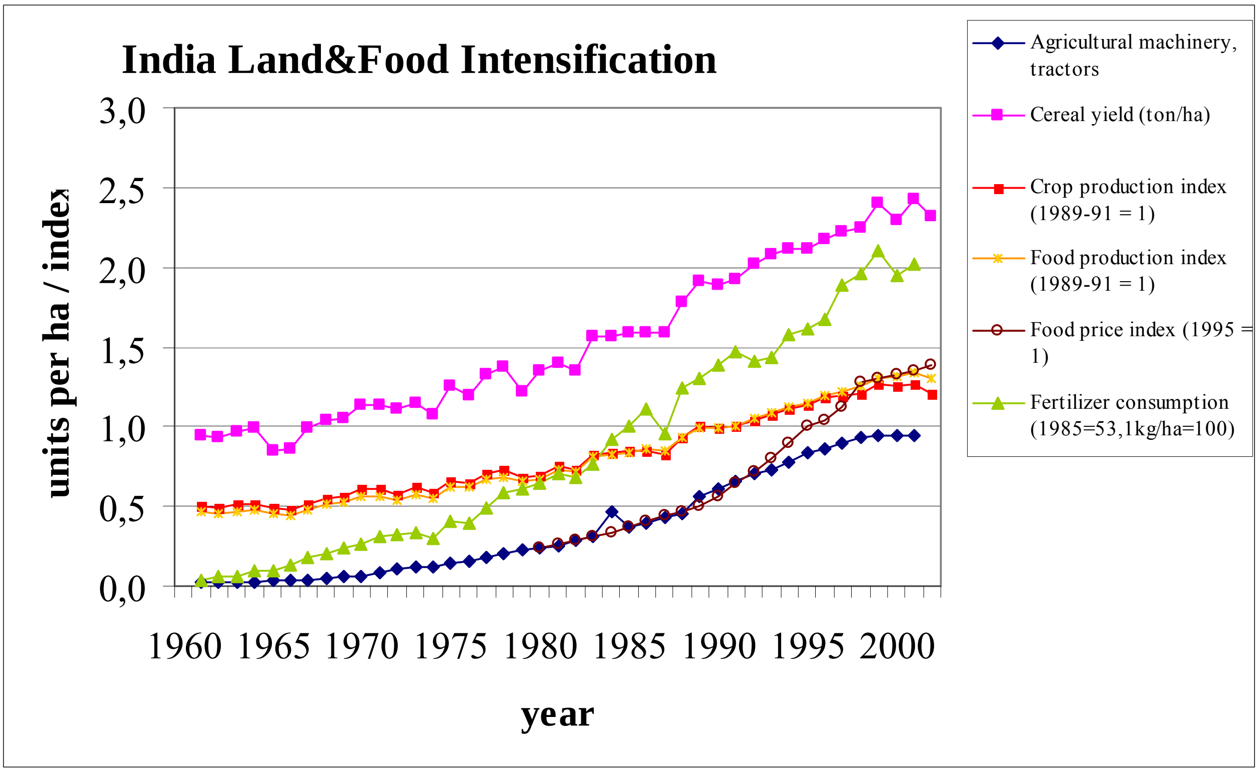


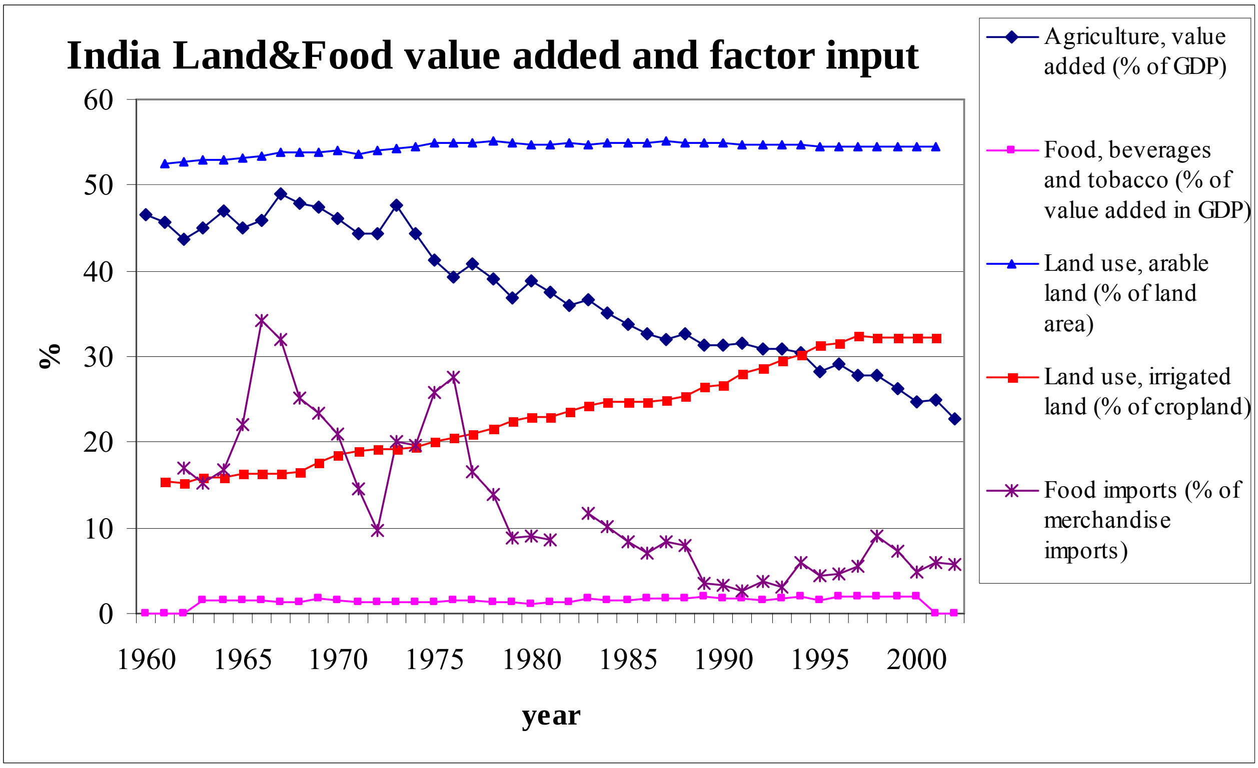
# TOTAL AREA UNDER OIL SEEDS



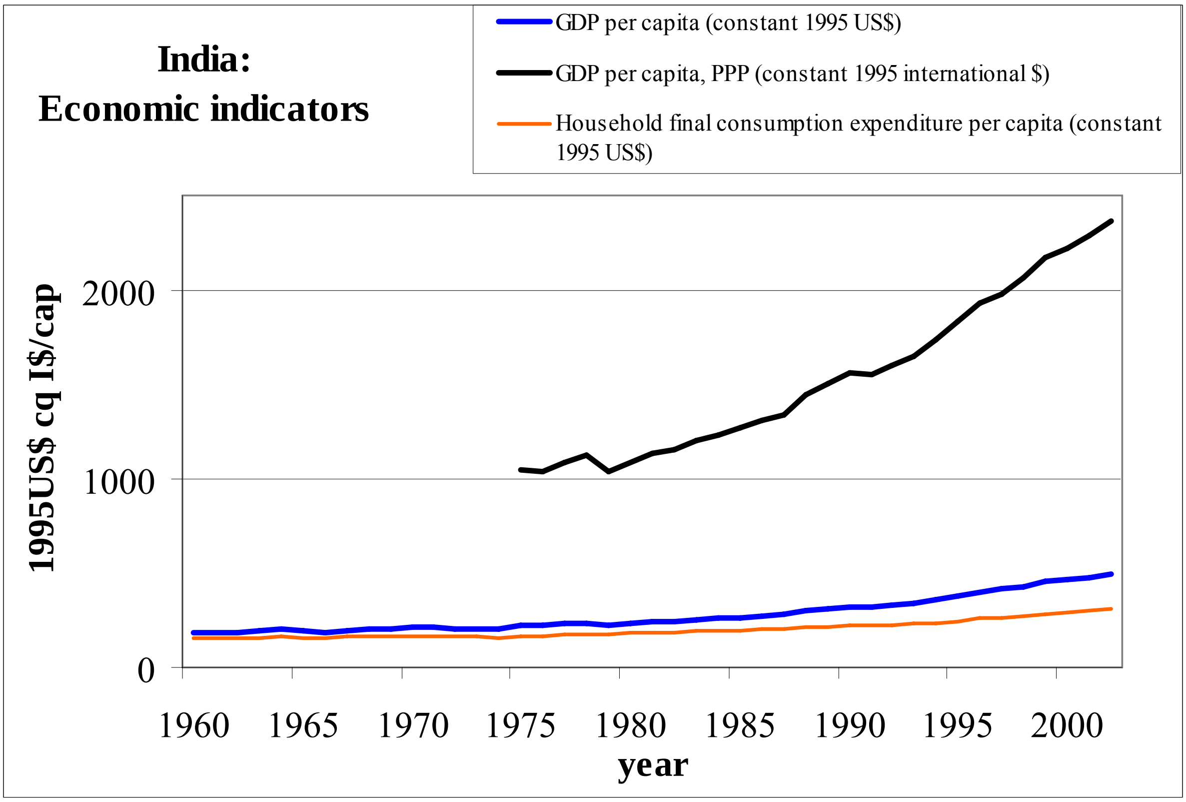

# TOTAL AREA UNDER SUGARCANE

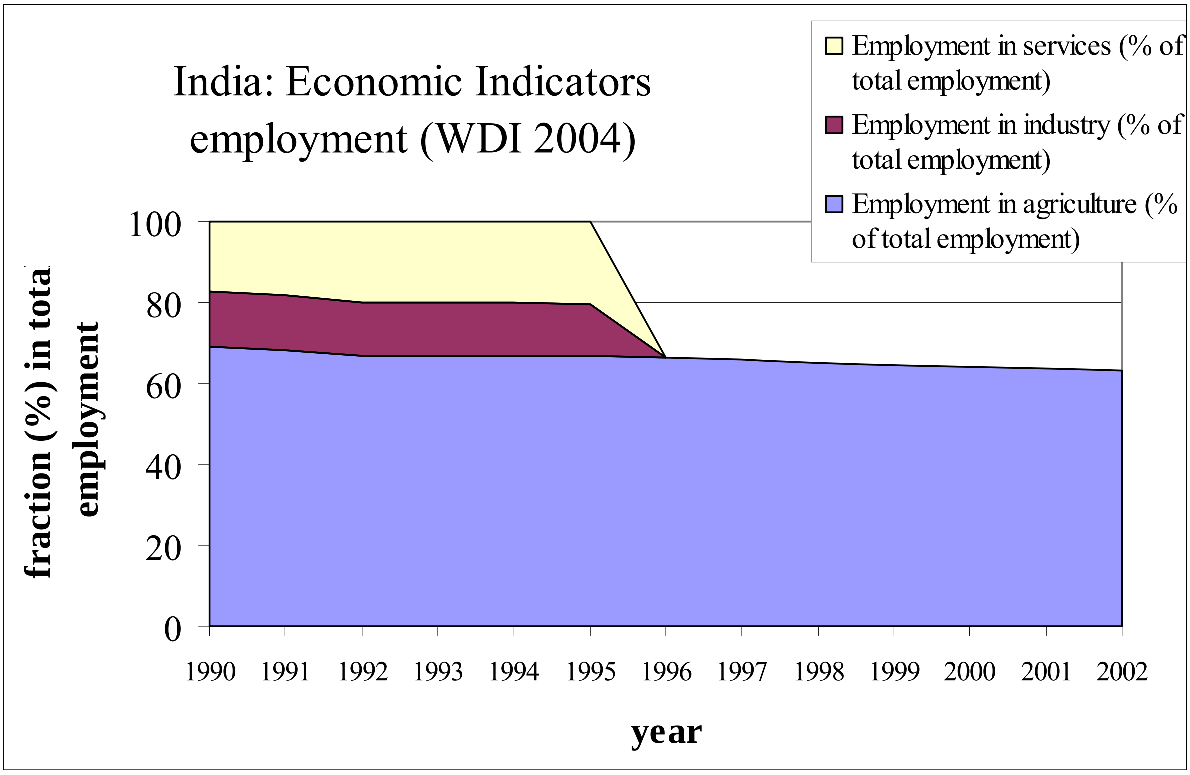


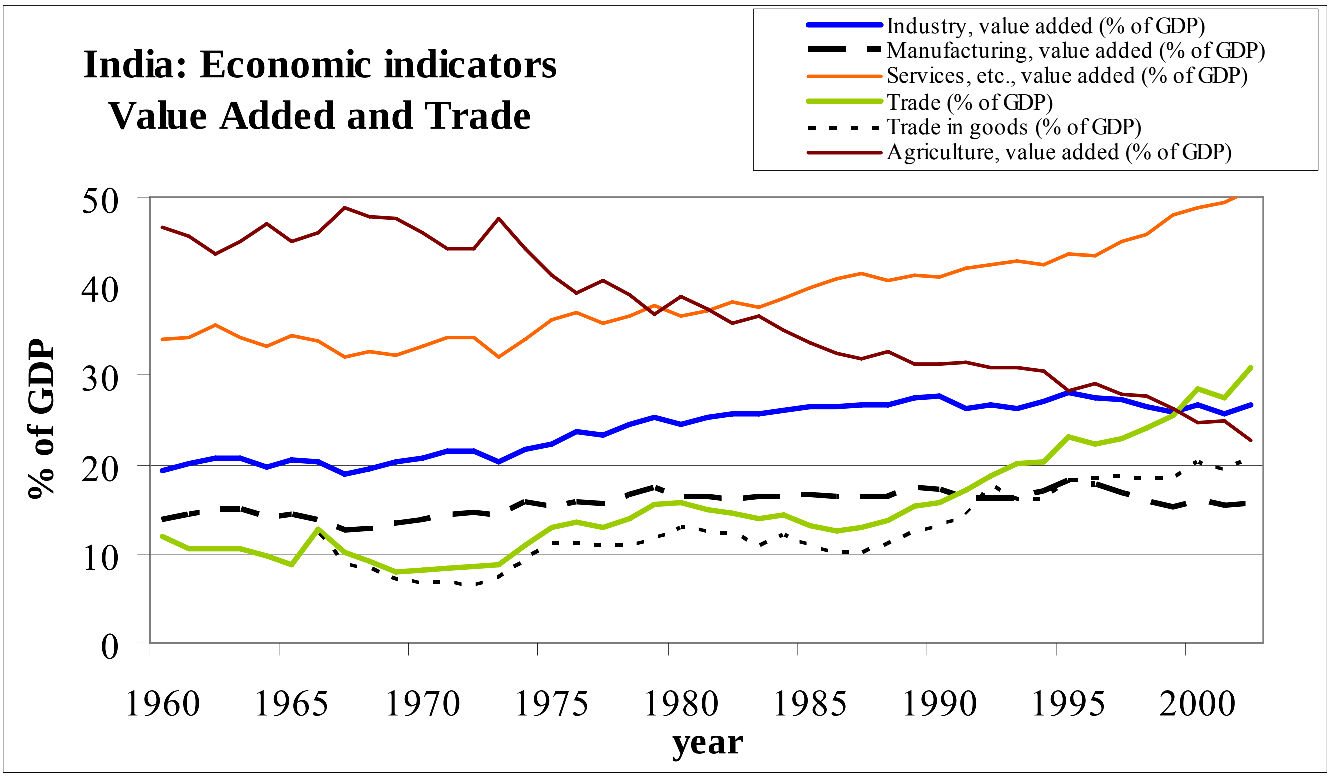

India Land&Food Intensification
units per ha / index
3,0
2,5
2,0
1,5
1,0
0,5
0,0
1960 1965 1970 1975 1980 1985 1990 1995 2000
year
Agricultural machinery, tractors
Cereal yield (ton/ha)
Crop production index (1989-91 = 1)
Food production index (1989-91 = 1)
Food price index (1995 = 1)
Fertilizer consumption (1985=53,1kg/ha=100)

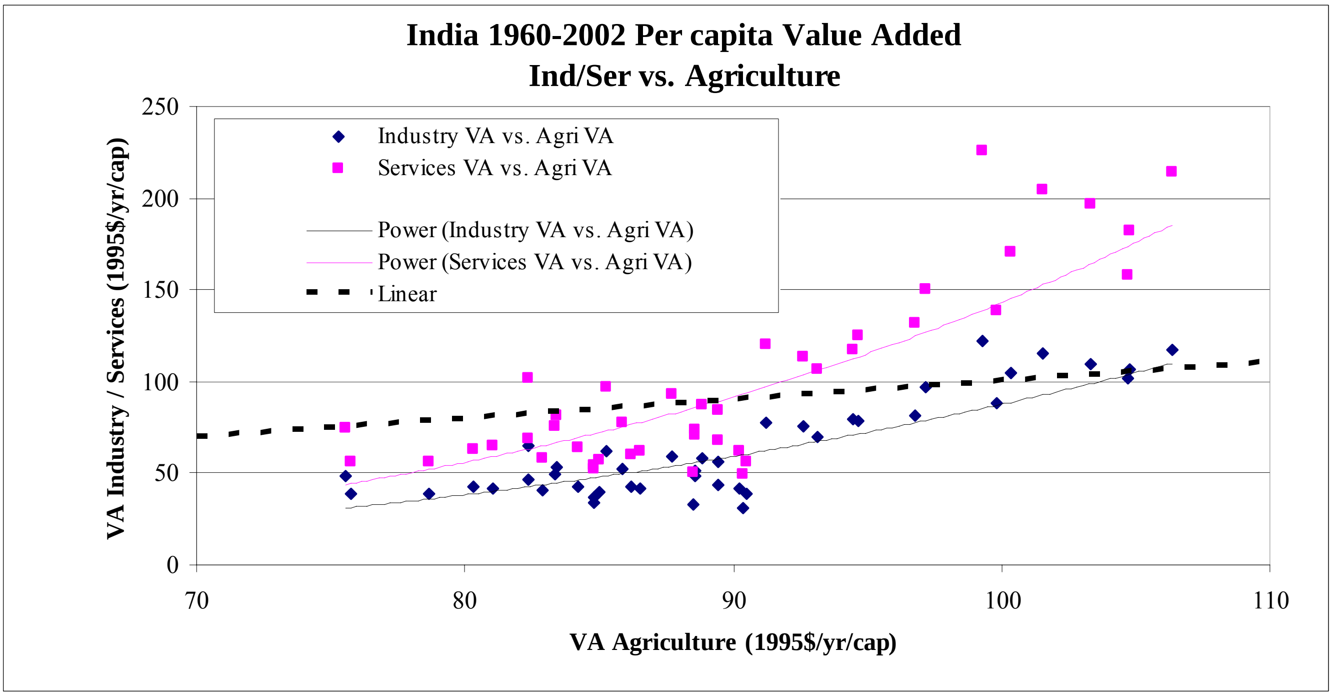

India Land&Food value added and factor input
%
60
50
40
30
20
10
0
1960 1965 1970 1975 1980 1985 1990 1995 2000
year
Agriculture, value added (% of GDP)
Food, beverages and tobacco (% of value added in GDP)
Land use, arable land (% of land area)
Land use, irrigated land (% of cropland)
Food imports (% of merchandise imports)

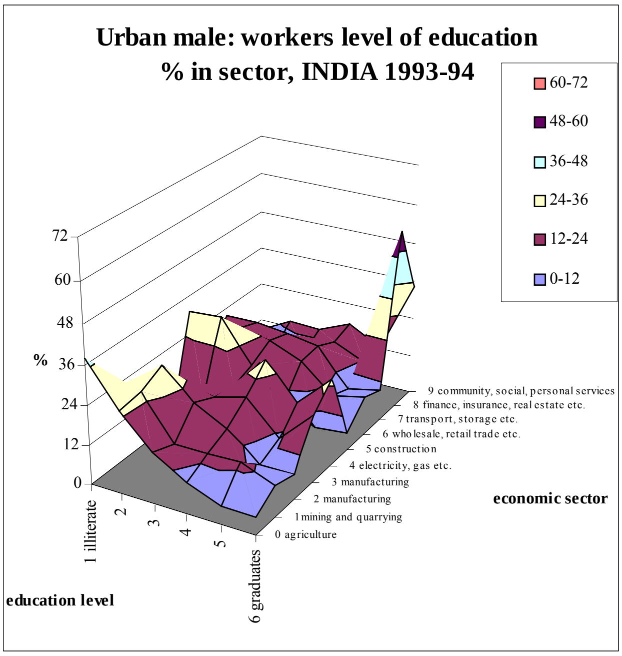
*Economy*

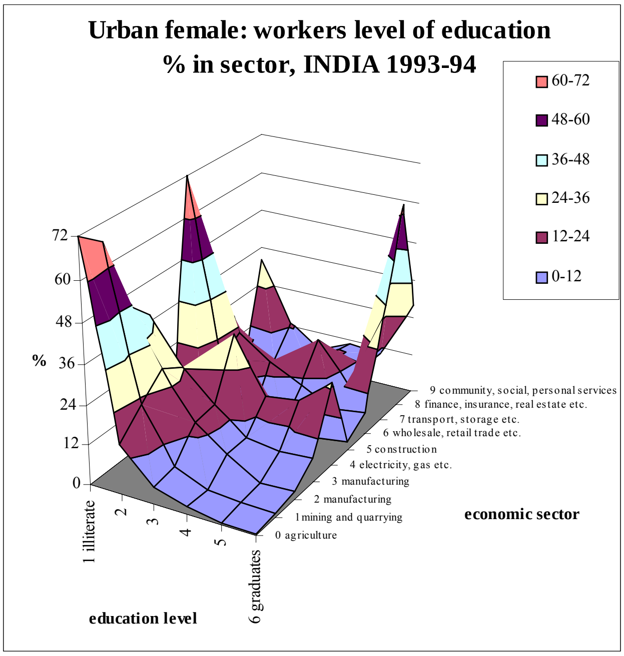

India:
Economic indicators
GDP per capita (constant 1995 US$)
GDP per capita, PPP (constant 1995 international $)
Household final consumption expenditure per capita (constant 1995 US$)
1995US$ cq I$/cap
2000
1000
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
year

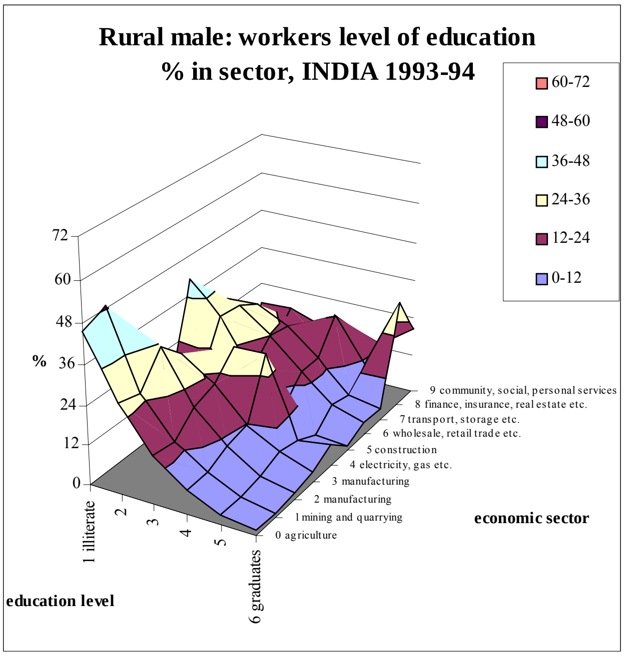

India: Economic Indicators
employment (WDI 2004)
Employment in services (% of total employment)
Employment in industry (% of total employment)
Employment in agriculture (% of total employment)
fraction (%) in tota employment
100
80
60
40
20
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
year

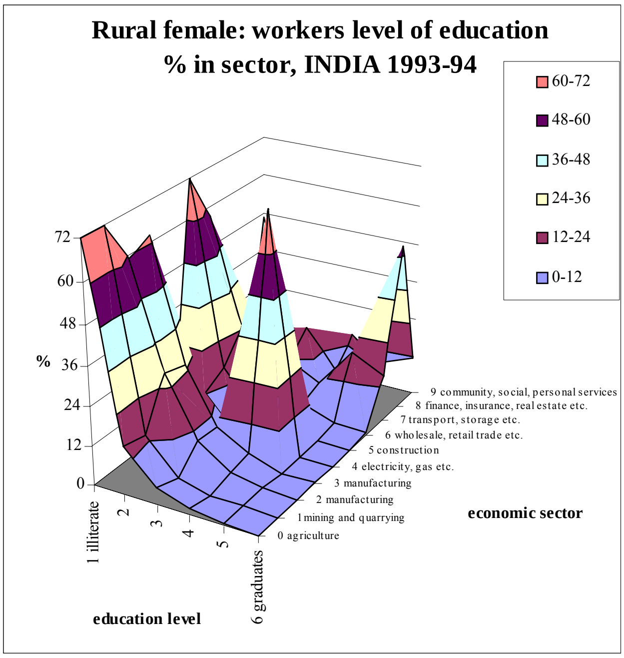

India: Economic indicators
Value Added and Trade
Industry, value added (% of GDP)
Manufacturing, value added (% of GDP)
Services, etc., value added (% of GDP)
Trade (% of GDP)
Trade in goods (% of GDP)
Agriculture, value added (% of GDP)
% of GDP
0
10
20
30
40
50
1960
1965
1970
1975
1980
1985
1990
1995
2000
year


India 1960-2002 Per capita Value Added
Ind/Ser vs. Agriculture
Industry VA vs. Agri VA
Services VA vs. Agri VA
Power (Industry VA vs. Agri VA)
Power (Services VA vs. Agri VA)
Linear
VA Industry / Services (1995$/yr/cap)
0
50
100
150
200
250
70
80
90
100
110
VA Agriculture (1995$/yr/cap)


Urban male: workers level of education
% in sector, INDIA 1993-94
60-72
48-60
36-48
24-36
12-24
0-12
72
60
48
%
36
24
12
0
1 illiterate
2
3
4
5
6 graduates
education level
9 community, social, personal services
8 finance, insurance, real estate etc.
7 transport, storage etc.
6 wholesale, retail trade etc.
5 construction
4 electricity, gas etc.
3 manufacturing
2 manufacturing
1 mining and quarrying
0 agriculture
economic sector


Urban female: workers level of education
% in sector, INDIA 1993-94
60-72
48-60
36-48
24-36
12-24
0-12
72
60
48
%
36
24
12
0
1 illiterate
2
3
4
5
6 graduates
education level
9 community, social, personal services
8 finance, insurance, real estate etc.
7 transport, storage etc.
6 wholesale, retail trade etc.
5 construction
4 electricity, gas etc.
3 manufacturing
2 manufacturing
1 mining and quarrying
0 agriculture
economic sector


Rural male: workers level of education
% in sector, INDIA 1993-94
60-72
48-60
36-48
24-36
12-24
0-12
72
60
48
%
36
24
12
0
1 illiterate
2
3
4
5
6 graduates
education level
9 community, social, personal services
8 finance, insurance, real estate etc.
7 transport, storage etc.
6 wholesale, retail trade etc.
5 construction
4 electricity, gas etc.
3 manufacturing
2 manufacturing
1 mining and quarrying
0 agriculture
economic sector


Rural female: workers level of education
% in sector, INDIA 1993-94
60-72
48-60
36-48
24-36
12-24
0-12
72
60
48
%
36
24
12
0
1 illiterate
2
3
4
5
6 graduates
education level
9 community, social, personal services
8 finance, insurance, real estate etc.
7 transport, storage etc.
6 wholesale, retail trade etc.
5 construction
4 electricity, gas etc.
3 manufacturing
2 manufacturing
1 mining and quarrying
0 agriculture
economic sector

**I-O coefficients: Ratio 1998 over 1978**

| **Sector**<br>**Commodity** | **Agriculture** | **Energy** | **Materials** | **Manufactures** | **Services** |
|---|---|---|---|---|---|
| **Agriculture** | **4,6** | **7,7** | **0,7** | **0,9** | **0,5** |
| **Energy** | **0,9** | **0,9** | **1,7** | **1,7** | **1,6** |
| **Materials** | **1,7** | **0,7** | **1,1** | **1,0** | **0,5** |
| **Manufactures** | **0,9** | **1,1** | **0,6** | **0,9** | **0,9** |
| **Services** | **1,9** | **1,7** | **1,2** | **1,2** | **0,7** |

Economic structural change: ratio of India 1998 over 1978 I-O coefficients

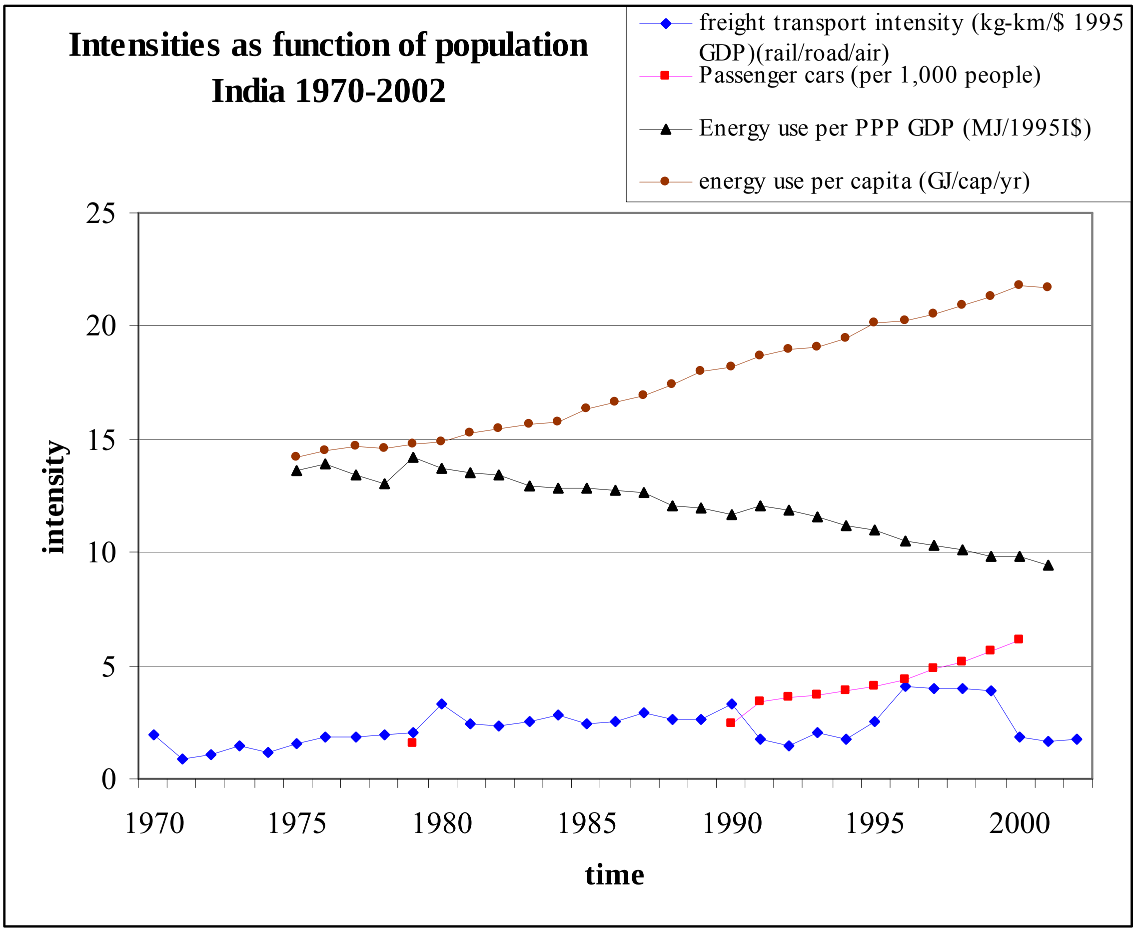
| | **Agriculture** | **Energy** | **Materials** | **Manufactures** | **Services** |
|---|---|---|---|---|---|
| **Agriculture** | **0,047** | **0,000** | **0,083** | **0,013** | **0,040** |
| **Energy** | **0,014** | **0,420** | **0,054** | **0,027** | **0,030** |
| **Materials** | **0,032** | **0,020** | **0,272** | **0,310** | **0,056** |
| **Manufactures** | **0,009** | **0,046** | **0,038** | **0,082** | **0,045** |
| **Services** | **0,045** | **0,084** | **0,148** | **0,141** | **0,199** |
| **Total** | *0,148* | *0,571* | *0,596* | *0,573* | *0,370* |
| **Net Indirect Taxes** | 0,011 | 0,049 | 0,077 | 0,080 | 0,040 |
| **Gross Value Added** | **0,524** | **0,380** | **0,327** | **0,346** | **0,591** |
| **Gross Output** | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |

Economic structure: India 1978 I-O coefficients (from 60x60 to IFs level)

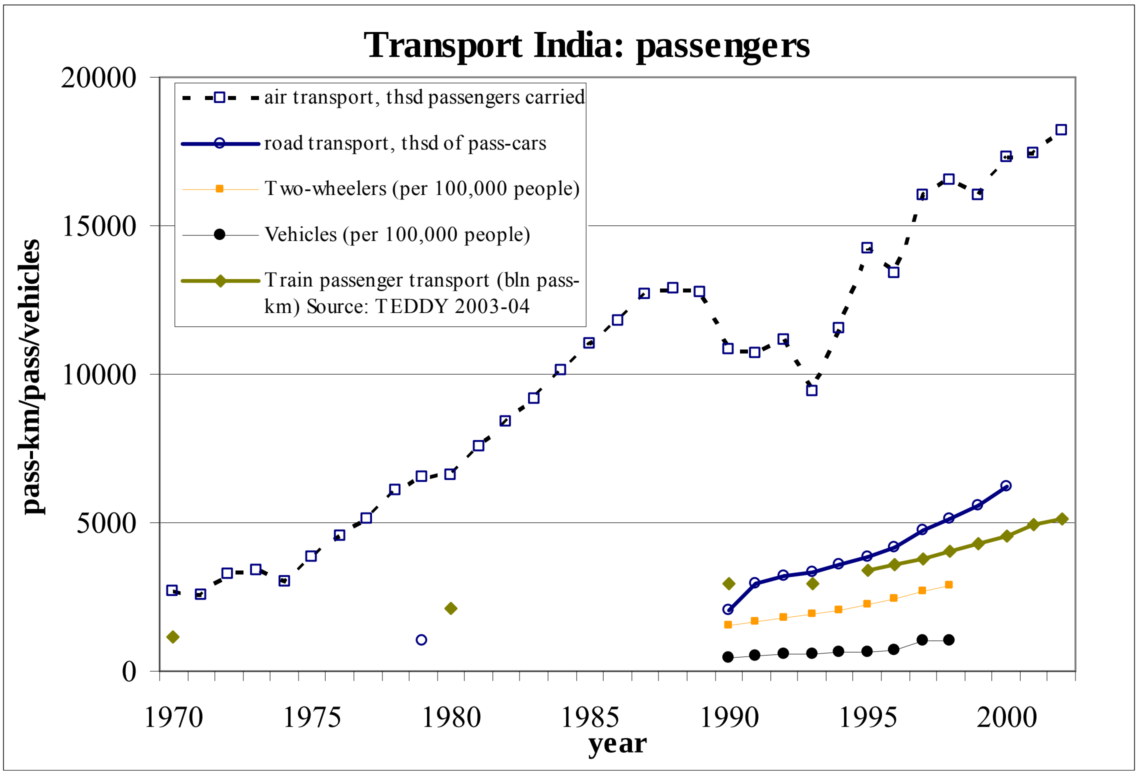
| | **Agriculture** | **Energy** | **Materials** | **Manufactures** | **Services** |
|---|---|---|---|---|---|
| **Agriculture** | **0,214** | **0,002** | **0,058** | **0,011** | **0,021** |
| **Energy** | **0,013** | **0,377** | **0,092** | **0,047** | **0,048** |
| **Materials** | **0,055** | **0,015** | **0,310** | **0,312** | **0,029** |
| **Manufactures** | **0,008** | **0,050** | **0,023** | **0,075** | **0,042** |
| **Services** | **0,087** | **0,145** | **0,182** | **0,167** | **0,142** |
| **Total Inputs at Factor Cost** | *0,376* | *0,589* | *0,665* | *0,611* | *0,282* |
| **Net Indirect Tax** | -0,013 | 0,031 | 0,034 | 0,058 | 0,025 |
| **Total Inputs at Purchaser's Price** | 0,150 | 0,620 | 0,655 | 0,669 | 0,306 |
| **Gross Value Added** | **0,850** | **0,380** | **0,345** | **0,331** | **0,694** |
| **GROSS Value of Output** | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |

Economic structure: India 1998 I-O coefficients (from 115x115 to IFs level)

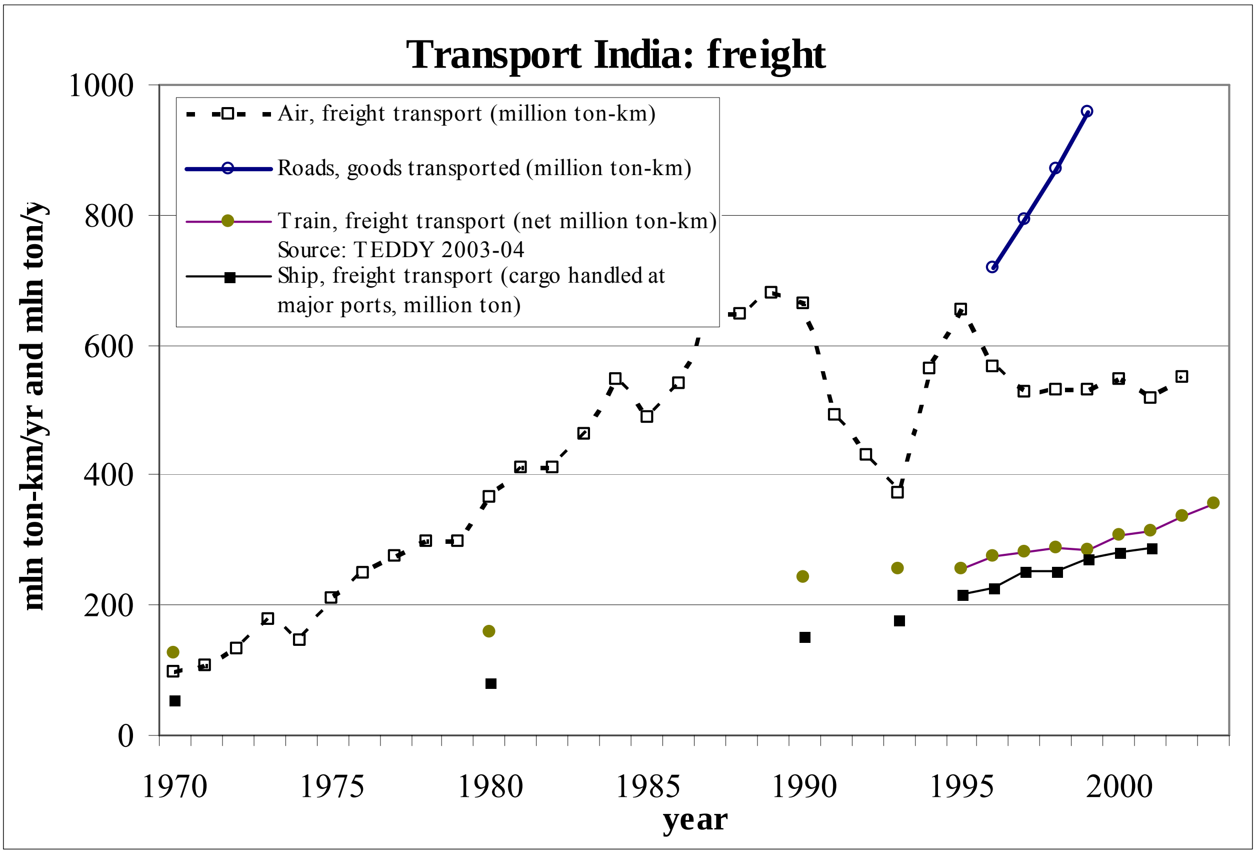
*Energy*

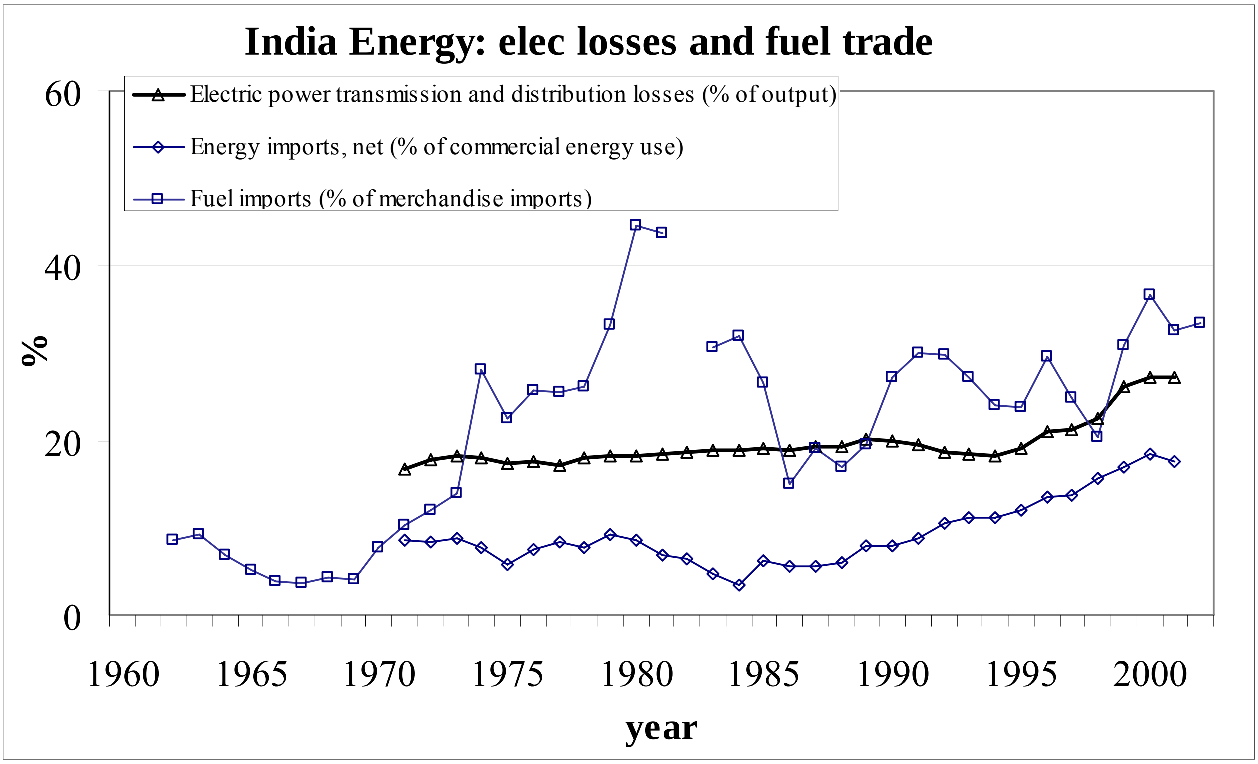


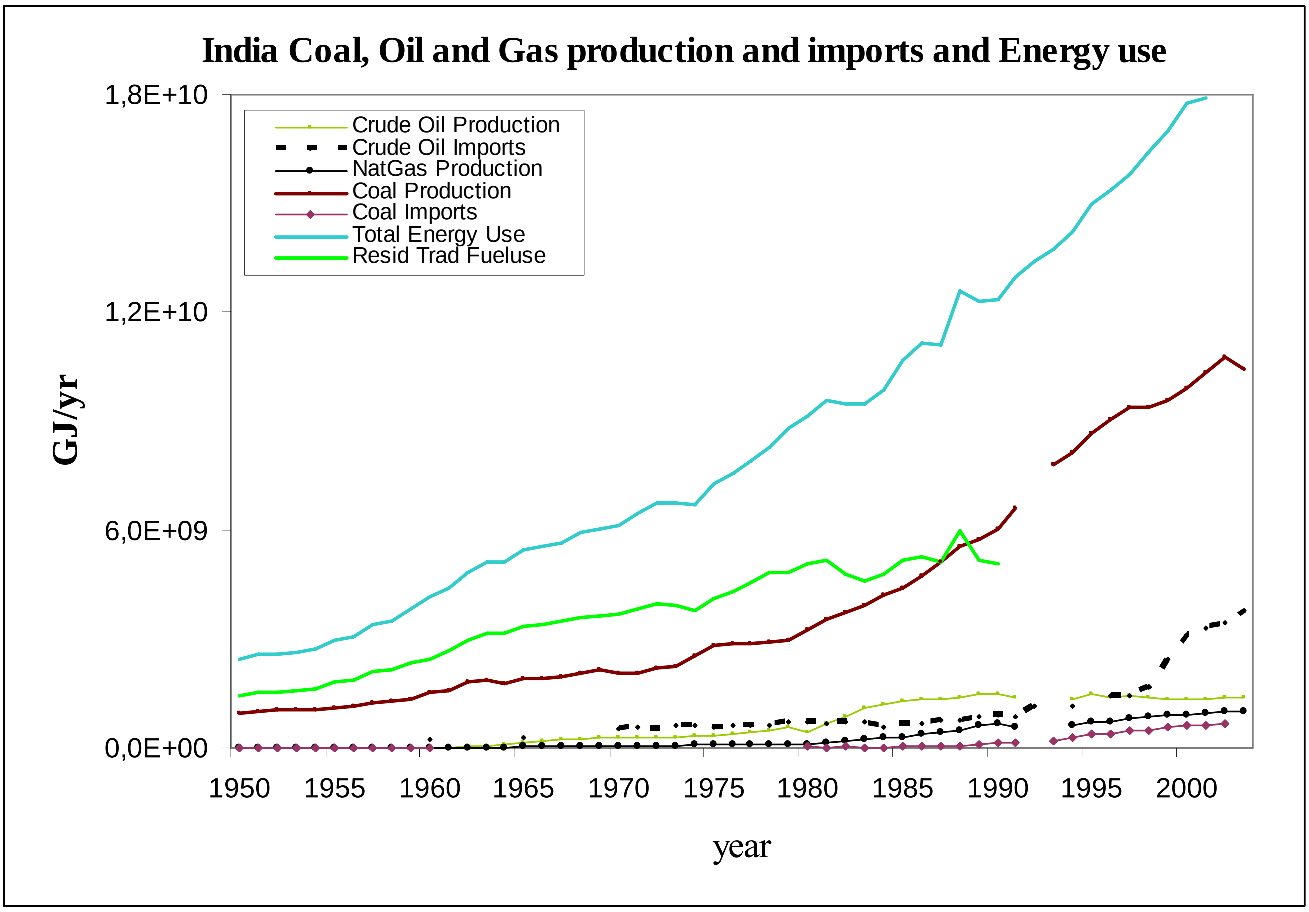
Intensities as function of population
India 1970-2002
freight transport intensity (kg-km/$ 1995 GDP)(rail/road/air)
Passenger cars (per 1,000 people)
Energy use per PPP GDP (MJ/1995I$)
energy use per capita (GJ/cap/yr)
intensity
0
5
10
15
20
25
1970
1975
1980
1985
1990
1995
2000
time

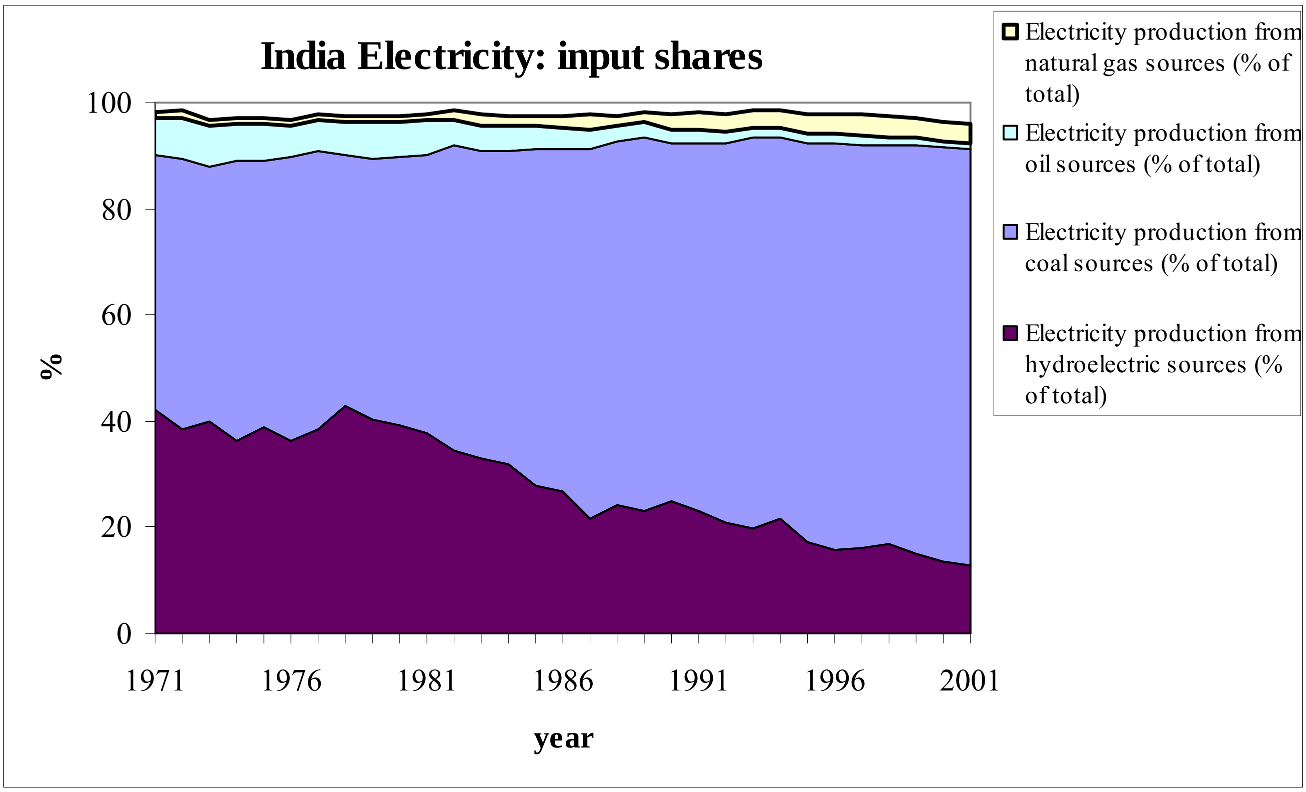



Transport India: passengers
air transport, thsd passengers carried
road transport, thsd of pass-cars
Two-wheelers (per 100,000 people)
Vehicles (per 100,000 people)
Train passenger transport (bln pass-km) Source: TEDDY 2003-04
pass-km/pass/vehicles
0
5000
10000
15000
20000
1970
1975
1980
1985
1990
1995
2000
year


Transport India: freight
Air, freight transport (million ton-km)
Roads, goods transported (million ton-km)
Train, freight transport (net million ton-km)
Source: TEDDY 2003-04
Ship, freight transport (cargo handled at major ports, million ton)
mln ton-km/yr and mln ton/y
1000
800
600
400
200
0
1970
1975
1980
1985
1990
1995
2000
year

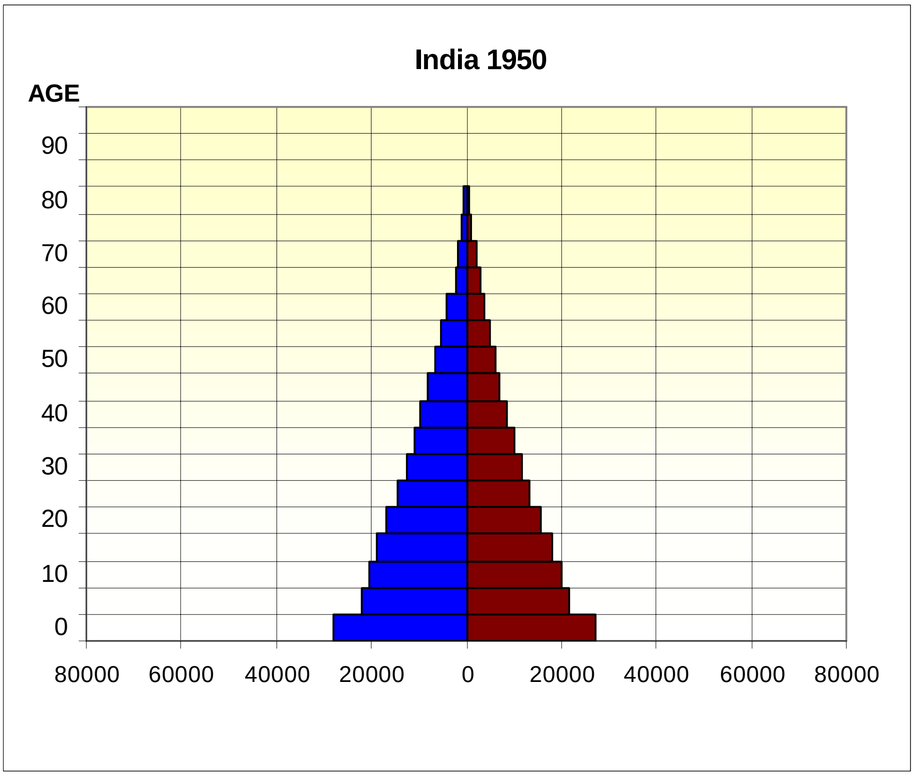

India Energy: elec losses and fuel trade
Electric power transmission and distribution losses (% of output)
Energy imports, net (% of commercial energy use)
Fuel imports (% of merchandise imports)
%
60
40
20
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
year

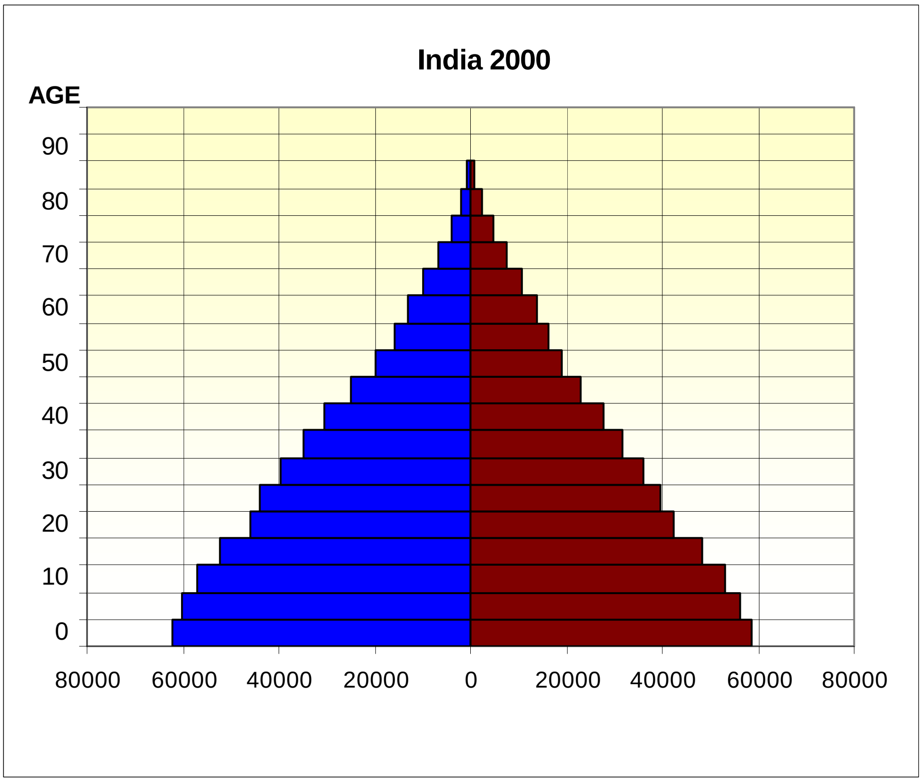

India Coal, Oil and Gas production and imports and Energy use
Crude Oil Production
Crude Oil Imports
NatGas Production
Coal Production
Coal Imports
Total Energy Use
Resid Trad Fueluse
1,8E+10
1,2E+10
6,0E+09
0,0E+00
GJ/yr
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
year

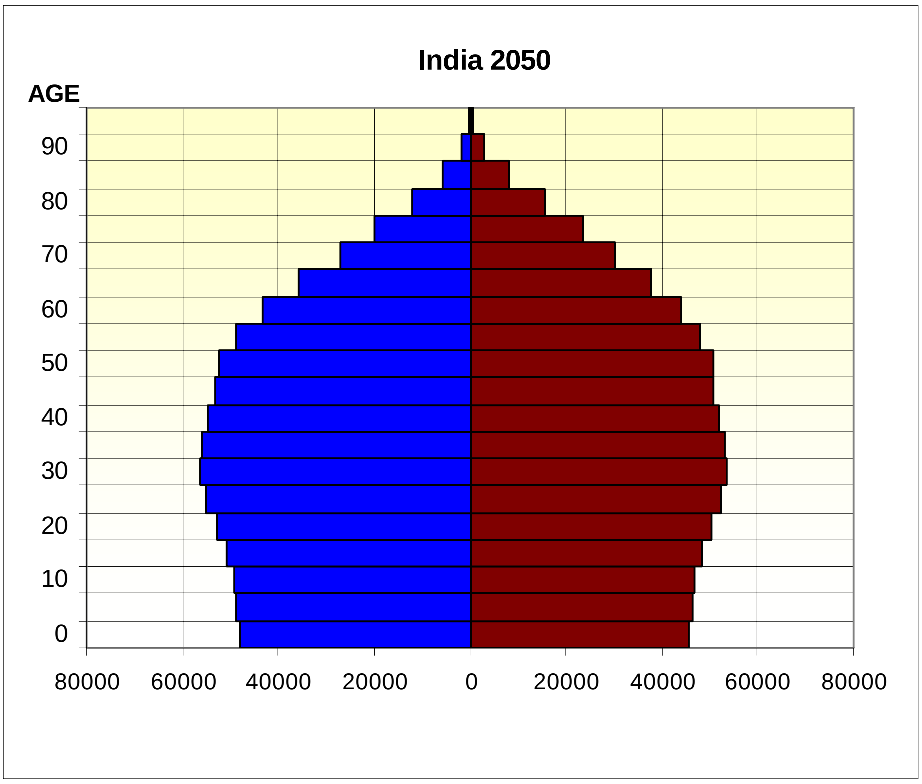

India Electricity: input shares
Electricity production from natural gas sources (% of total)
Electricity production from oil sources (% of total)
Electricity production from coal sources (% of total)
Electricity production from hydroelectric sources (% of total)
100
80
60
40
20
0
%
1971
1976
1981
1986
1991
1996
2001
year

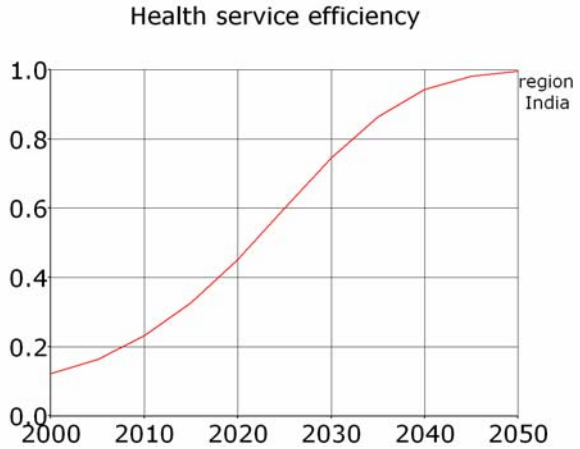
# Annex D Demographic projections

***Population pyramid for India 1950-2000-2050*** (Medium Population Projection UN (2004) – personal communication H. Hilderink)



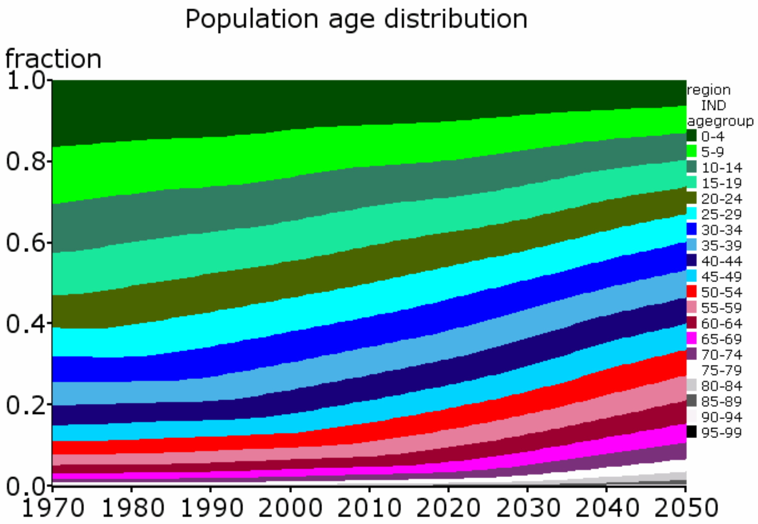



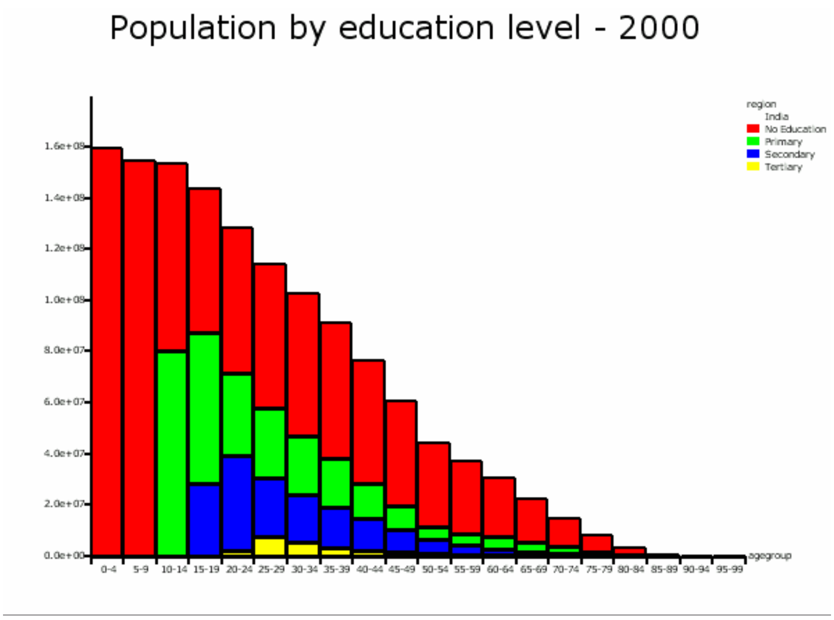


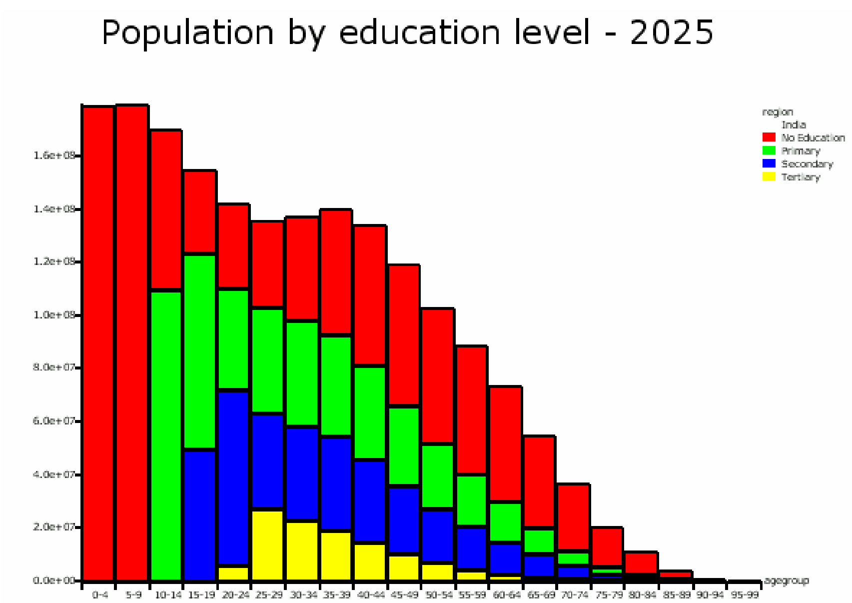



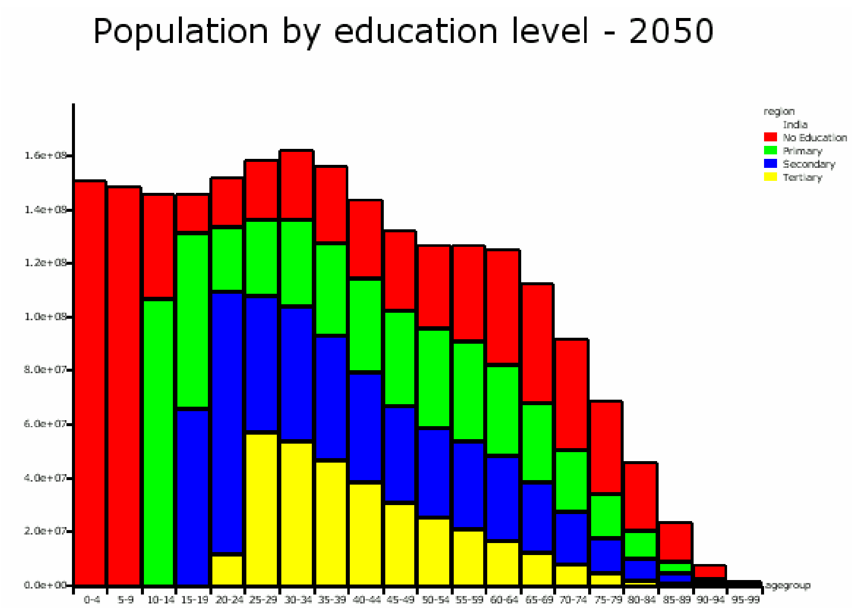

*Example of a scenario-based model assumption: the increase in the effectiveness of health service expenditures.*

*Age distribution of the Indian population 1970–2050, as simulated with the PHOENIX-model.*




Population by education level - 2000
region
India
No Education
Primary
Secondary
Tertiary
0.0e+00
2.0e+07
4.0e+07
6.0e+07
8.0e+07
1.0e+08
1.2e+08
1.4e+08
1.6e+08
agegroup
0-4 5-9 10-14 15-19 20-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60-64 65-69 70-74 75-79 80-84 85-89 90-94 95-99


Population by education level - 2025
region
India
No Education
Primary
Secondary
Tertiary
0.0e+00
2.0e+07
4.0e+07
6.0e+07
8.0e+07
1.0e+08
1.2e+08
1.4e+08
1.6e+08
agegroup
0-4 5-9 10-14 15-19 20-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60-64 65-69 70-74 75-79 80-84 85-89 90-94 95-99


Population by education level - 2050
region
India
No Education
Primary
Secondary
Tertiary
0.0e+00
2.0e+07
4.0e+07
6.0e+07
8.0e+07
1.0e+08
1.2e+08
1.4e+08
1.6e+08
agegroup
0-4 5-9 10-14 15-19 20-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60-64 65-69 70-74 75-79 80-84 85-89 90-94 95-99

# Annex E Input-output (I-O) classification

## *Sector categories in the I-O tables for India*

| S.No. | 1978-79 and 1983-84<br>Industry / Commodity | 1989-90, 1993-94 and 1998-99<br>COMMODITY / INDUSTR |
|---|---|---|
| 1 | Food Crops | Paddy |
| 2 | Cash Crops | Wheat |
| 3 | Plantation Crops | Jowar |
| 4 | Other Crops | Bajra |
| 5 | Animal Husbandry | Maize |
| 6 | Forestry & Logging | Gram |
| 7 | Fishing | Pulses |
| 8 | Coal & Lignite | Sugarcane |
| 9 | Crude Petro., Natural Gas | Groundnut |
| 10 | Iron Ore | Jute |
| 11 | Other Minerals | Cotton |
| 12 | Sugar | Tea |
| 13 | Food Products excl. Sugar | Coffee |
| 14 | Beverages | Rubber |
| 15 | Tobacco Products | Coconut |
| 16 | Cotton Textiles | Tobacco |
| 17 | Wool, Silk, Synth. Textiles | Other crops |
| 18 | Jute, Hemp & Mista Textiles | Milk and milk products |
| 19 | Textiles Products | Animal services (agricultu |
| 20 | Wood, Prod. Excl. Furniture | Other livestock products |
| 21 | Furniture, Fixtures | Forestry and logging |
| 22 | Paper, Paper Products | Fishing |
| 23 | Print, Publ. & Allied Activiti | Coal and Lignite |
| 24 | Leather, Lather Products | Crude petroleum, natural |
| 25 | Plastic, Rubber Products | Iron ore |
| 26 | Petroleum Products | Manganese ore |
| 27 | Coal Tar Products | Bauxite |
| 28 | Inorganic Heavy Chemicals | Copper ore |
| 29 | Organic Heavy Chemicals | Other metallic minerals |
| 30 | Ferrtilizers | Limestone |
| 31 | Paints, Varnishes, Lacquers | Mica |
| 32 | Pesti. Drugs, Other Chemical | Other non metallic minera |
| 33 | Cement | Sugar |
| 34 | Non-Metallic Minerals | Khandsari, boora |
| 35 | Iron, Steel Foundries | Hydrogenated oil (vanasp |
| 36 | Other Basic Metal Industries | Edible oils other than van |
| 37 | Metal Product, Excl. Machin | Tea and coffee processin |
| 38 | Agricultural Machinery | Miscellaneous food produ |
| 39 | Machinery for Food/ Tex. Inc | Beverages |
| 40 | Other Machineries | Tobacco products |
| 41 | Electronic, Elec. Machinery | Khadi, cotton textiles (han |
| 42 | Railway Transport Equipmen | Cotton textiles |
| 43 | Other Transport Equipment | Woolen textiles |
| 44 | Misc. Manfu. Industries | Silk textiles |
| 45 | Construction | Art silk, synthetic fiber tex |
| 46 | Electricity | Jute, hemp, mesta textile |
| 47 | Gas & Water Supply | Carpet weaving |
| 48 | Railway Transport Service | Readymade garments |
| 49 | Other Transport Services | Miscellaneous textile prod |
| 50 | Storage & Warehousing | Furniture and fixtures-wo |
| 51 | Communication | Wood and wood products |
| 52 | Trade | Paper, paper prods. & ne |
| 53 | Hotels & Restaurants | Printing and publishing |
| 54 | Banking | Leather footwear |
| 55 | Insurance | Leather and leather produ |
| 56 | Ownership of Dwellings | Rubber products |
| 57 | Education & Research | Plastic products |
| 58 | Medical & Health | Petroleum products |
| 59 | Other Services | Coal tar products |
| 60 | Public Administration & Def | Inorganic heavy chemical |

| | |
|---|---|
| 61 | Organic heavy chemicals |
| 62 | Fertilizers |
| 63 | Pesticides |
| 64 | Paints, varnishes and lacc |
| 65 | Drugs and medicines |
| 66 | Soaps, cosmetics & glycer |
| 67 | Synthetic fibers, resin |
| 68 | Other chemicals |
| 69 | Structural clay products |
| 70 | Cement |
| 71 | Other non-metallic minera |
| 72 | Iron, steel and ferro alloys |
| 73 | Iron and steel casting & fo |
| 74 | Iron and steel foundries |
| 75 | Non-ferrous basic metals |
| 76 | Hand tools, hardware |
| 77 | Miscellaneous metal prod |
| 78 | Tractors and agri. implem |
| 79 | Industrial machinery (F&T |
| 80 | Industrial machinery (othe |
| 81 | Machine tools |
| 82 | Office computing machine |
| 83 | Other non-electrical mach |
| 84 | Electrical industrial Machir |
| 85 | Electrical wires & cables |
| 86 | Batteries |
| 87 | Electrical appliances |
| 88 | Communication equipmer |
| 89 | Other electrical Machinery |
| 90 | Electronic equipments(inc |
| 91 | Ships and boats |
| 92 | Rail equipments |
| 93 | Motor vehicles |
| 94 | Motor cycles and scooters |
| 95 | Bicycles, cycle-rickshaw |
| 96 | Other transport equipmen |
| 97 | Watches and clocks |
| 98 | Miscellaneous manufactur |
| 99 | Construction |
| 100 | Electricity |
| 101 | Gas |
| 102 | Water supply |
| 103 | Railway transport services |
| 104 | Other transport services |
| 105 | Storage and warehousing |
| 106 | Communication |
| 107 | Trade |
| 108 | Hotels and restaurants |
| 109 | Banking |
| 110 | Insurance |
| 111 | Ownership of dwellings |
| 112 | Education and research |
| 113 | Medical and health |
| 114 | Other services |
| 115 | Public administration |

## *Aggregation of post-1983-1994 I-O categories from 115 to 60*

| Sector # | 60-sector Matrix | Sector # | 115-sector Matrix |
|---|---|---|---|
| 1 | Food Crops | **1** | **Paddy** |
| 2 | Cash Crops | **8** | **Sugarcane** |
| 3 | Plantation Crops | **12** | **Tea** |
| 4 | Other Crops | **17** | **Other crops** |
| 5 | Animal Husbandry | **18** | **Milk and milk products** |
| 6 | Forestry & Logging | **21** | **Forestry and logging** |
| 7 | Fishing | **22** | **Fishing** |
| 8 | Coal & Lignite | **23** | **Coal and lignite** |
| 9 | Crude Petroleum & Natural Gas | **24** | **Crude petroleum, natural gas** |
| 10 | Iron Ore | **25** | **Iron ore** |
| 11 | Other Minerals | **26** | **Manganese ore** |
| 12 | Sugar | **33** | **Sugar** |
| 13 | Food Products excl. Sugar | **35** | **Hydrogenated oil(vanaspati)** |
| 14 | Beverages | **39** | **Beverages** |
| 15 | Tobacco Products | **40** | **Tobacco products** |
| 16 | Cotton Textiles | **41** | **Khadi, cotton textiles(handlooms)** |
| 17 | Wool, Silk, Synthetic Textiles | **42** | **Cotton textiles** |
| 18 | Jute, Hemp & Mista Textiles | **46** | **Jute, hemp, mesta textiles** |
| 19 | Textile Products | **47** | **Carpet weaving** |
| 21 | Furniture & Fixtures | **50** | **Furniture and fixtures-wooden** |
| 20 | Wood Products (excl. Furniture) | **51** | **Wood and wood products** |
| 22 | Paper, Paper Products | **52** | **Paper, paper prods. & newsprint** |
| 23 | Print, Publishing & Allied Activities | **53** | **Printing and publishing** |
| 24 | Leather, Leather Products | **54** | **Leather footwear** |
| 25 | Plastic, Rubber Products | **57** | **Plastic products** |
| 26 | Petroleum Products | **58** | **Petroleum products** |
| 27 | Coal Tar Products | **59** | **Coal tar products** |
| 28 | Inorganic Heavy Chemicals | **60** | **Inorganic heavy chemicals** |
| 29 | Organic Heavy Chemicals | **61** | **Organic heavy chemicals** |
| 30 | Fertilisers | **62** | **Fertilizers** |
| 31 | Paints, Varnishes, Lacquers | **64** | **Paints, varnishes and lacquers** |
| 32 | Pesticides Drugs & Other Chemicals | **63** | **Pesticides** |
| 33 | Cement | **69** | **Structural clay products** |
| 34 | Non-Metallic Minerals | **71** | **Other non-metallic mineral prods.** |
| 35 | Iron, Steel Foundries | **72** | **Iron, steel and ferro alloys** |
| 36 | Other Basic Metal Industries | **75** | **Non-ferrous basic metals** |
| 37 | Metal Product (excl. Machinery) | **76** | **Hand tools, hardware** |
| 38 | Agricultural Machinery | **78** | **Tractors and agri. implements** |
| 39 | Machinery for Food/ Tex. Industries | **79** | **Industrial machinery(F & T)** |
| 40 | Other Machinery | **80** | **Industrial machinery(others)** |
| 41 | Electronic & Electrical Machinery | **84** | **Electrical industrial Machinery** |
| 42 | Railway Transport Equipment | **92** | **Rail equipments** |
| 43 | Other Transport Equipment | **91** | **Ships and boats** |
| 44 | Misc. Manufacturing Industries | **97** | **Watches and clocks** |
| 45 | Construction | **99** | **Construction** |
| 46 | Electricity | **100** | **Electricity** |
| 47 | Gas & Water Supply | **101** | **Gas** |
| 48 | Railway Transport Service | **103** | **Railway transport services** |
| 49 | Other Transport Services | **104** | **Other transport services** |
| 50 | Storage & Warehousing | **105** | **Storage and warehousing** |
| 51 | Communication | **106** | **Communication** |
| 52 | Trade | **107** | **Trade** |
| 53 | Hotels & Restaurants | **108** | **Hotels and restaurants** |
| 54 | Banking | **109** | **Banking** |
| 55 | Insurance | **110** | **Insurance** |
| 56 | Ownership of Dwellings | **111** | **Ownership of dwellings** |
| 57 | Education & Research | **112** | **Education and research** |
| 58 | Medical & Health | **113** | **Medical and health** |
| 59 | Other Services | **114** | **Other services** |
| 60 | Public Administration & Defence | **115** | **Public administration** |

### *Aggregation of 60 sectors of the I-O table to ten sectors (Pradan et al. 2006)*

C1 Agriculture (sector 1-7)

C2 Mining and Quarrying (sector 8-11)

C3 Manufacturing 1 (sector 12-24)

C4 Manufacturing 2 (sector 25-44)

C5 Electricity, Gas, etc. (sector 46 and 47)

C6 Construction (sector 45)

C7 Trade (sector 52 and 53)

C8 Transport, Storage, etc. 9sector 48-51)

C9 Financial, Real Estate, etc. (sector 54-56)

C10 Community Service (sector 57-60)

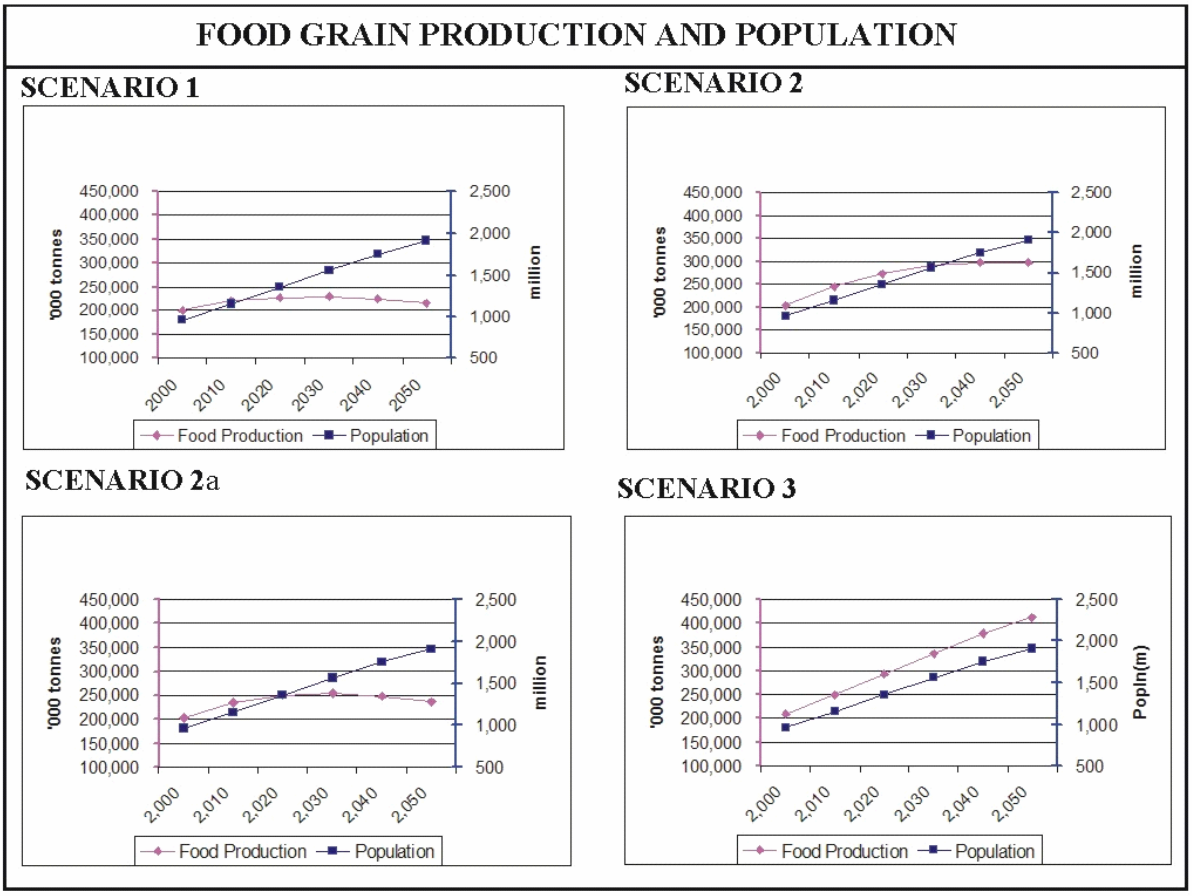
### *Economic sector aggregation from India I-O-matrices to IFs economic model*

| **IFs model I-O categories** | **1978** | **1983** | **1989** | **1993** | **1998** |
|---|---|---|---|---|---|
| **Sector(s)** | **% total FD** | **% total FD** | **% total FD** | **% total FD** | **% total FD** |
| **Agriculture** | **40,8%** | **38,0%** | **29,2%** | **33,2%** | **31,3%** |
| **Energy** | **-0,7%** | **-0,4%** | **-0,2%** | **-0,5%** | **-0,2%** |
| **Materials** | **10,2%** | **9,8%** | **7,7%** | **8,2%** | **5,4%** |
| **Manufactures** | **18,4%** | **18,3%** | **32,3%** | **19,9%** | **20,6%** |
| **Services** | **31,1%** | **33,4%** | **30,5%** | **39,2%** | **43,0%** |
| **ICTech** | **0,0%** | **0,0%** | **0,0%** | **0,0%** | **0,0%** |
| | *99,9%* | *99,1%* | *99,5%* | *100,0%* | *100,1%* |

| **Agriculture** | **Energy** | **Materials** | **Manufactures** | **Services** | **ICTech** |
|---|---|---|---|---|---|
| Food Crops | Coal & Lignite | Iron Ore | Metal Product (excl. Mac | Railway Transport Service | |
| Cash Crops | Crude Petroleum & Natu | Other Minerals | Agricultural Machinery | Other Transport Services | |
| Plantation Crops | Petroleum Products | Cotton Textiles | Machinery for Food/ Tex | Storage & Warehousing | |
| Other Crops | Coal Tar Products | Wool, Silk, Synthetic Te | Other Machinery | Communication | |
| Animal Husbandry | Electricity | Jute, Hemp & Mista Text | Electronic & Electrical M | Trade | |
| Forestry & Logging | Gas & Water Supply | Textile Products | Railway Transport Equip | Hotels & Restaurants | |
| Fishing | | Wood Products (excl. Fu | Other Transport Equipme | Banking | |
| Sugar | | Furniture & Fixtures | Misc. Manufacturing Ind | Insurance | |
| Food Products excl. Sugar | | Paper, Paper Products | Construction | Ownership of Dwellings | |
| Beverages | | Print, Publishing & Allied Activities | | Education & Research | |
| Tobacco Products | | Leather, Leather Products | | Medical & Health | |
| | | Plastic, Rubber Products | | Other Services | |
| | | Inorganic Heavy Chemicals | | Public Administration & Defence | |
| | | Organic Heavy Chemicals | | | |
| | | Fertilisers | | | |
| | | Paints, Varnishes, Lacquers | | | |
| | | Pesticides Drugs & Other Chemicals | | | |
| | | Cement | | | |
| | | Non-Metallic Minerals | | | |
| | | Iron, Steel Foundries | | | |
| | | Other Basic Metal Industries | | | |

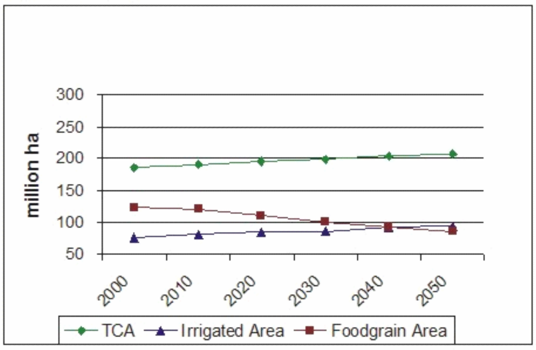
# Annex F Food and water projections

Food

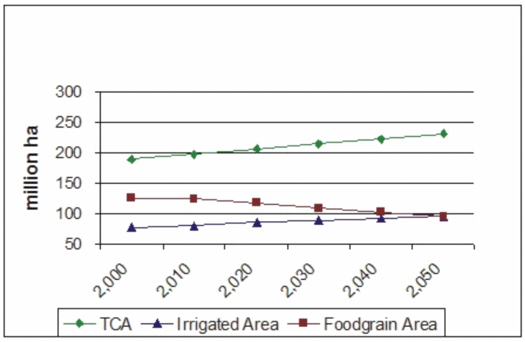


**CHANGE IN TOTAL CROPPED AREA, IRRIGATED AREA AND FOOD GRAIN AREA**

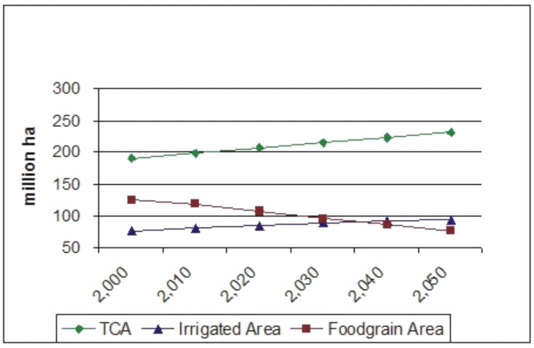
**SCENARIO 1**



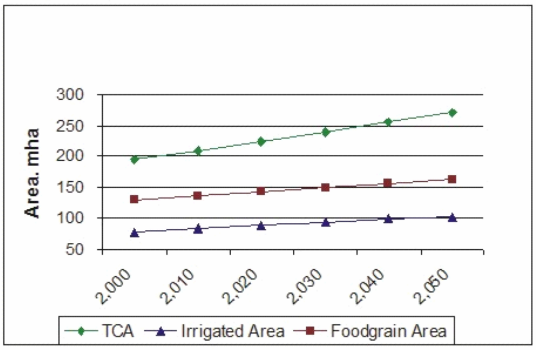

**SCENARIO 2**

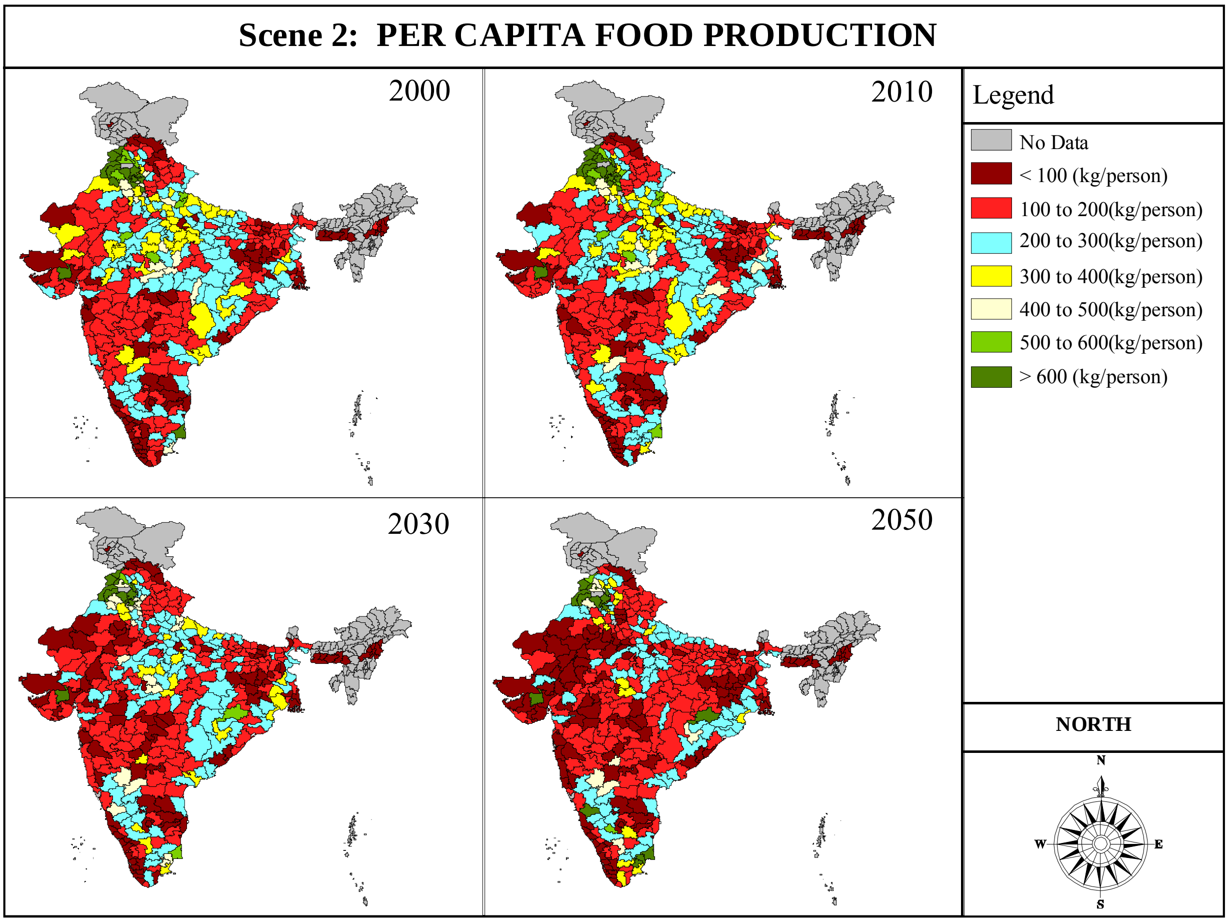



**SCENARIO 2a**

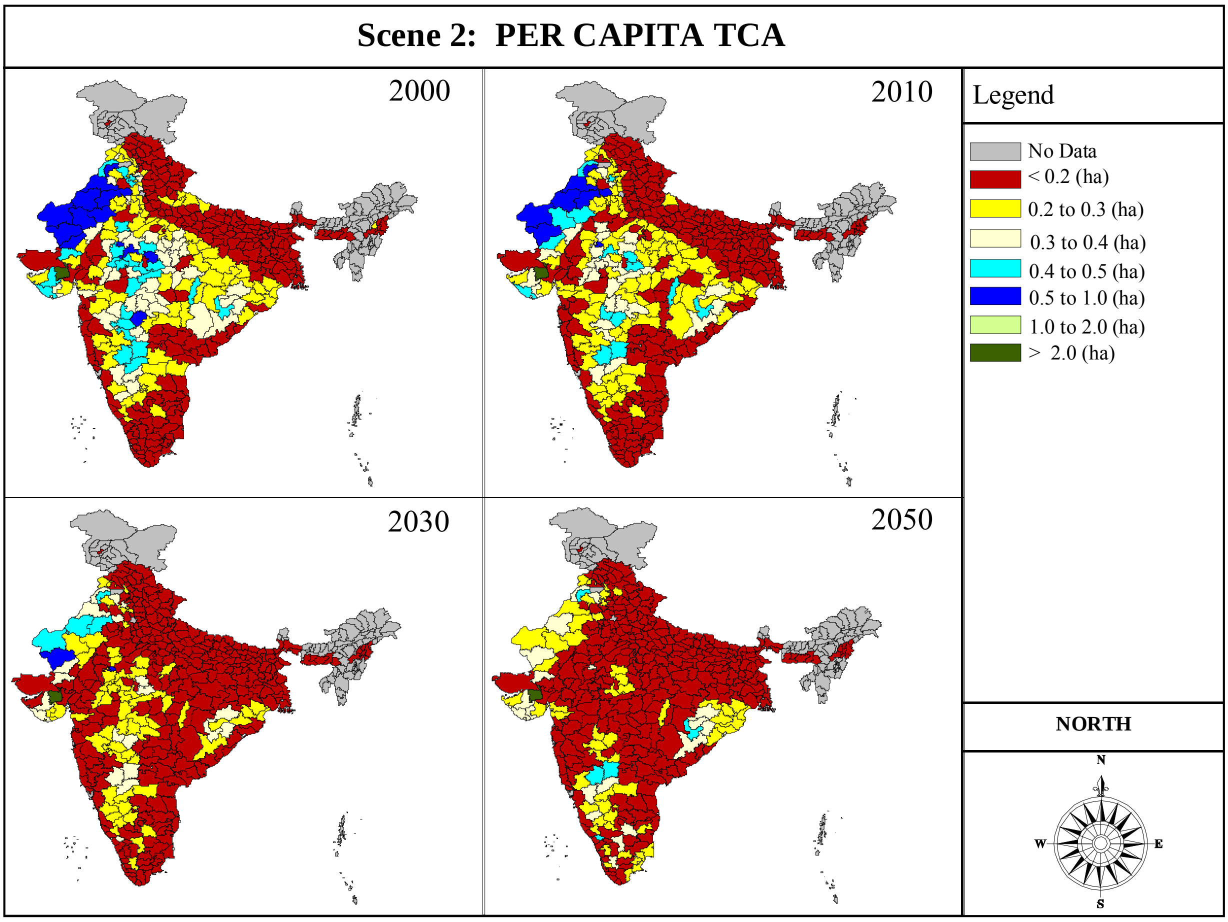



**SCENARIO 3**



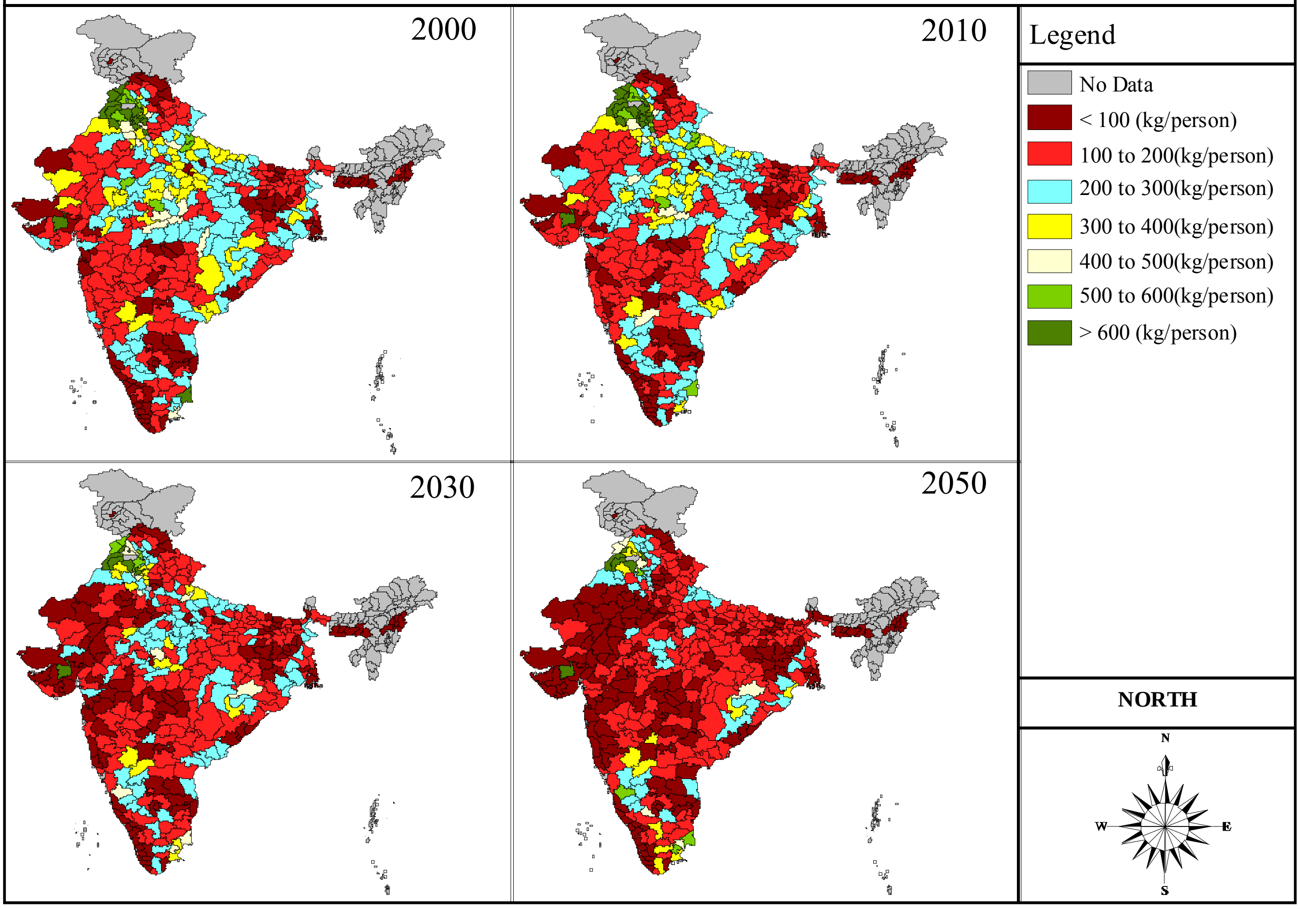


Scene 2: PER CAPITA FOOD PRODUCTION
2000
2010
2030
2050
Legend
No Data
< 100 (kg/person)
100 to 200(kg/person)
200 to 300(kg/person)
300 to 400(kg/person)
400 to 500(kg/person)
500 to 600(kg/person)
> 600 (kg/person)
NORTH
N
W
E
S

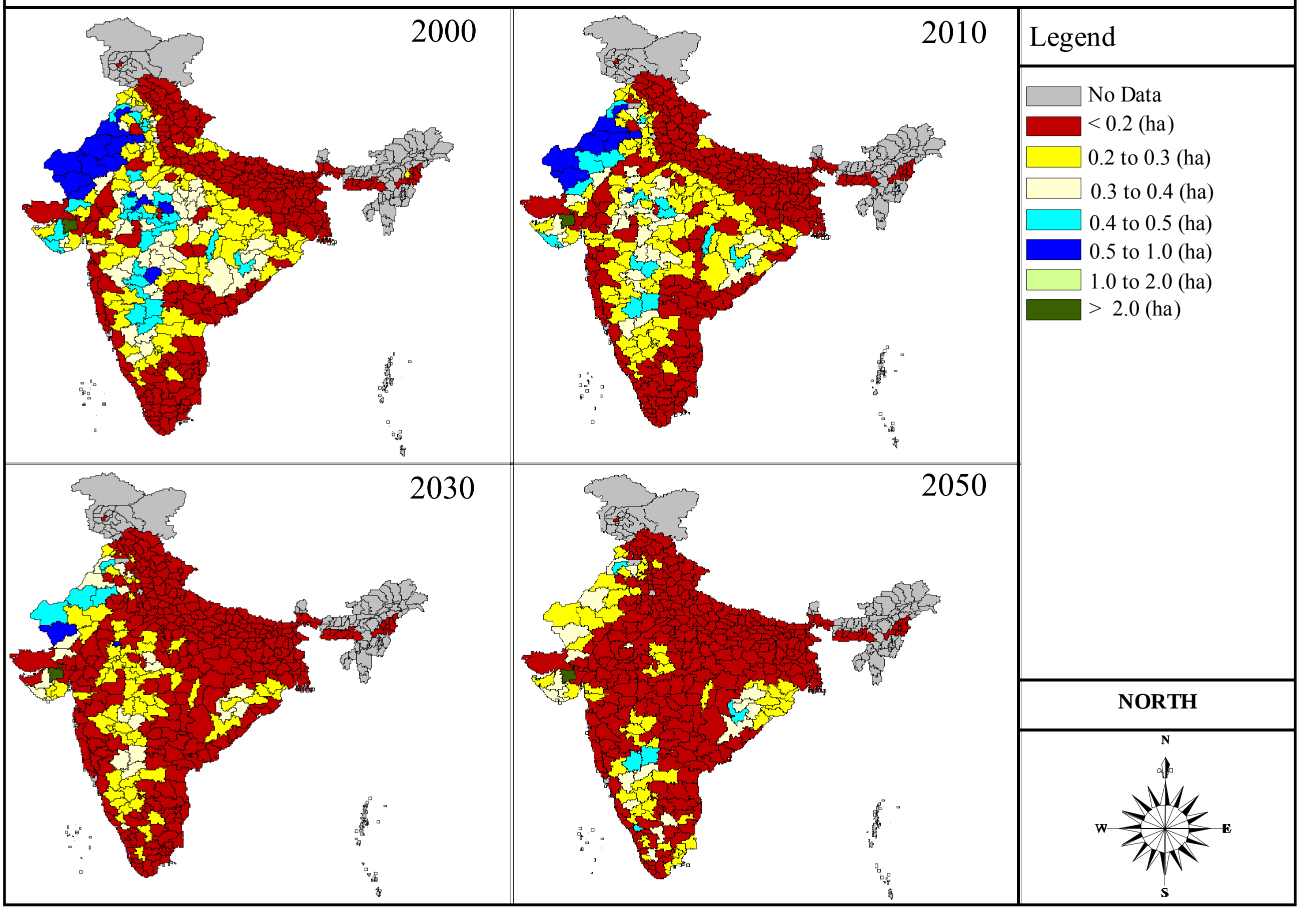



Scene 2: PER CAPITA TCA
2000
2010
2030
2050
Legend
No Data
< 0.2 (ha)
0.2 to 0.3 (ha)
0.3 to 0.4 (ha)
0.4 to 0.5 (ha)
0.5 to 1.0 (ha)
1.0 to 2.0 (ha)
> 2.0 (ha)
NORTH
N
W
E
S

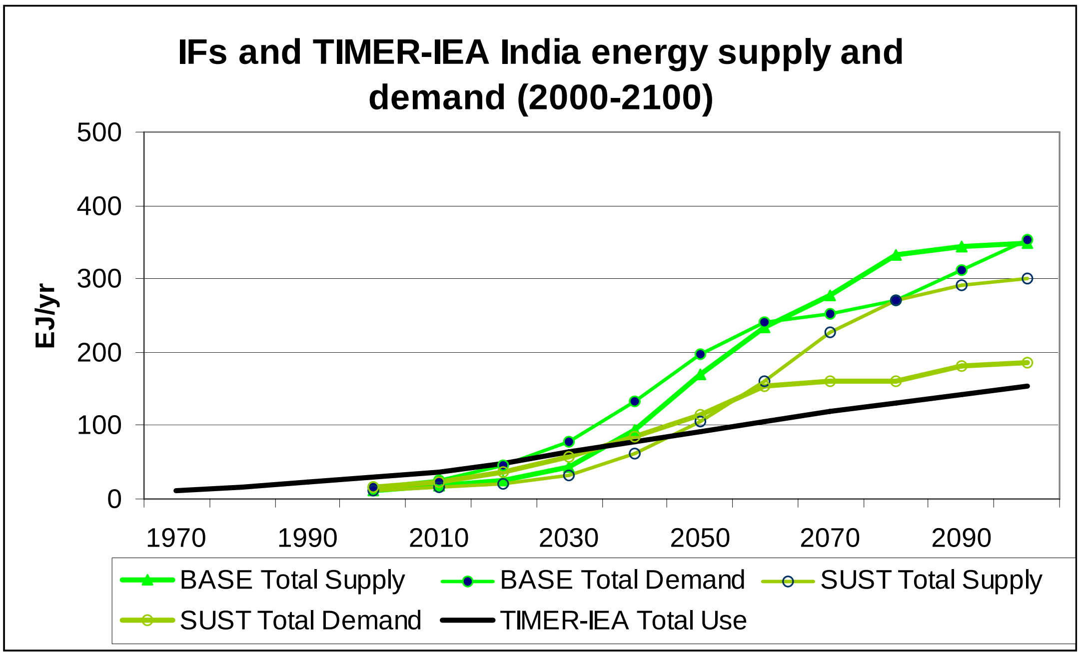
## Scenario 2a: PER CAPITA FOOD PRODUCTION



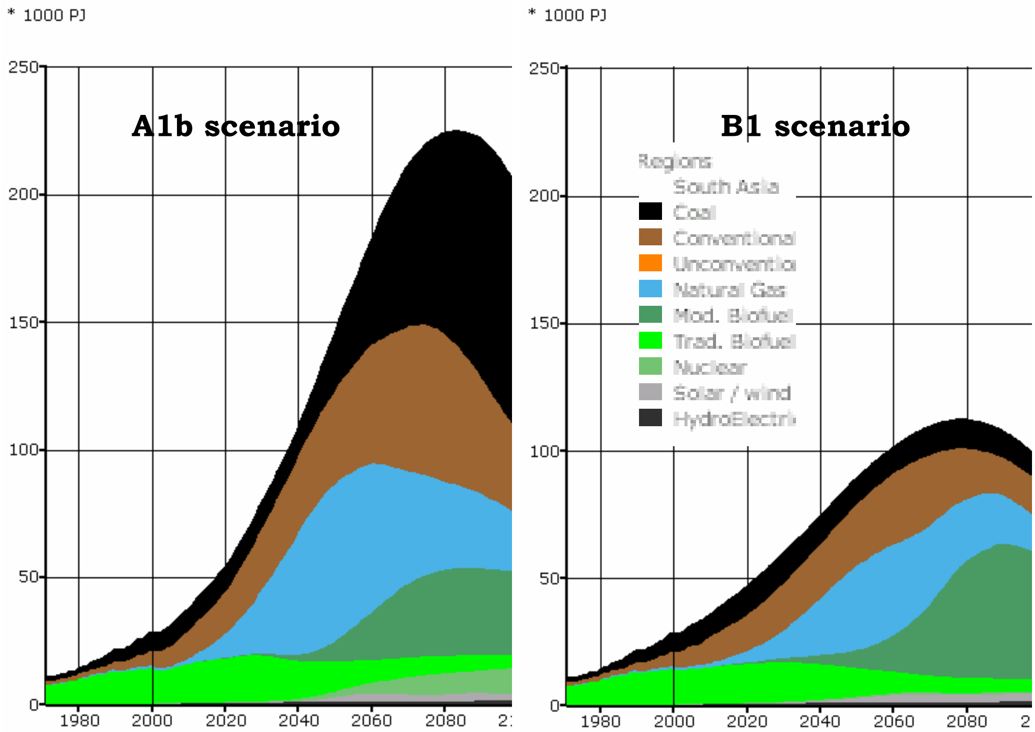

## Scenario 2a: PER CAPITA TCA



# Annex G Energy projections

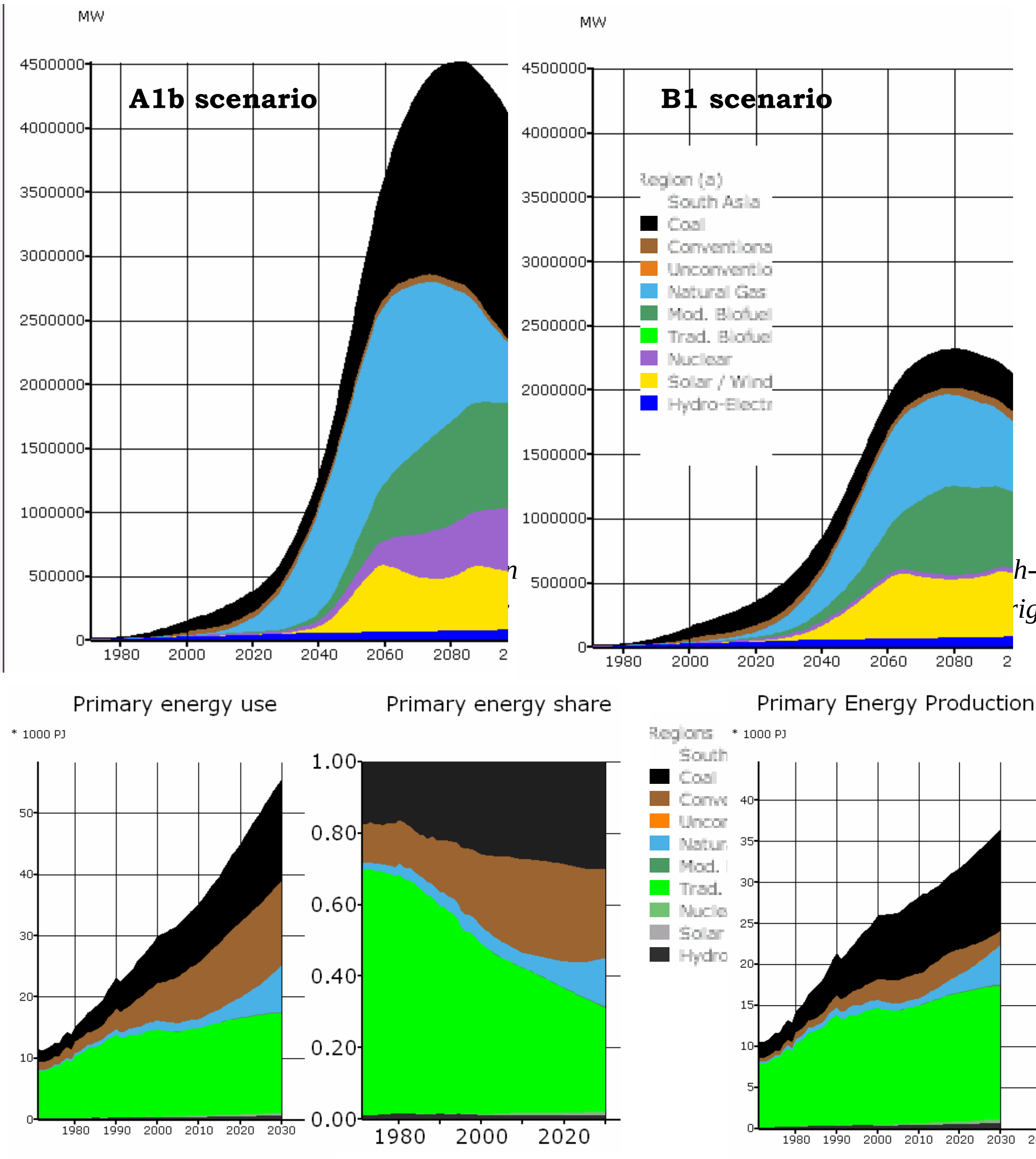



## Primary energy use – South Asia 1971-2100



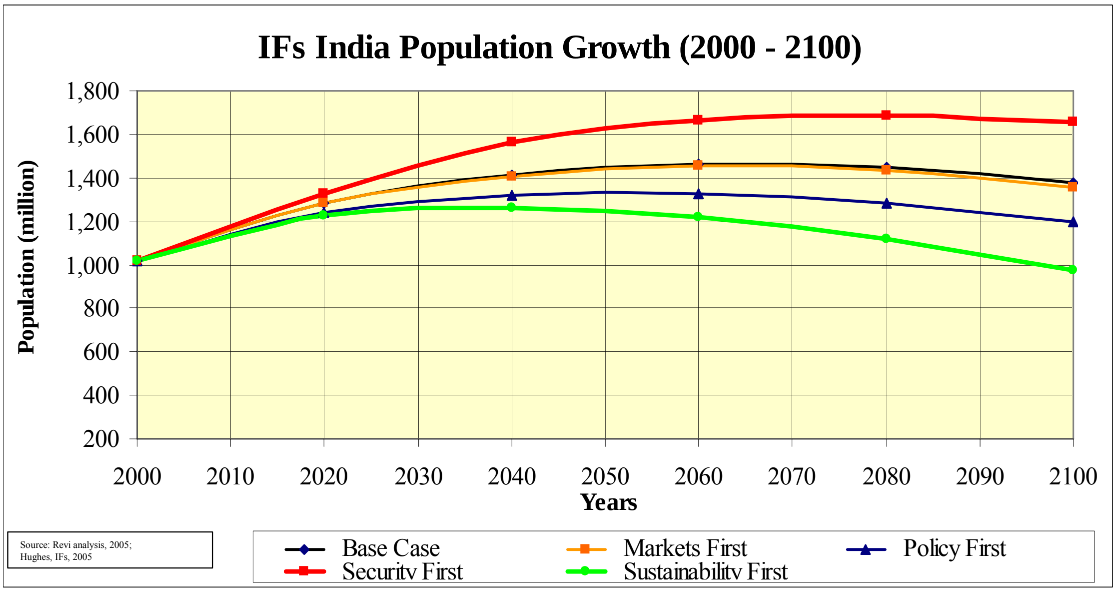

*Simulation of the primary energy use in the region South Asia for the high-growth high-tech scenario A1b (left) and the equity and environment oriented B1 scenario (right), as simulated with the TIMER-model (Van Vuuren et al 2005)*

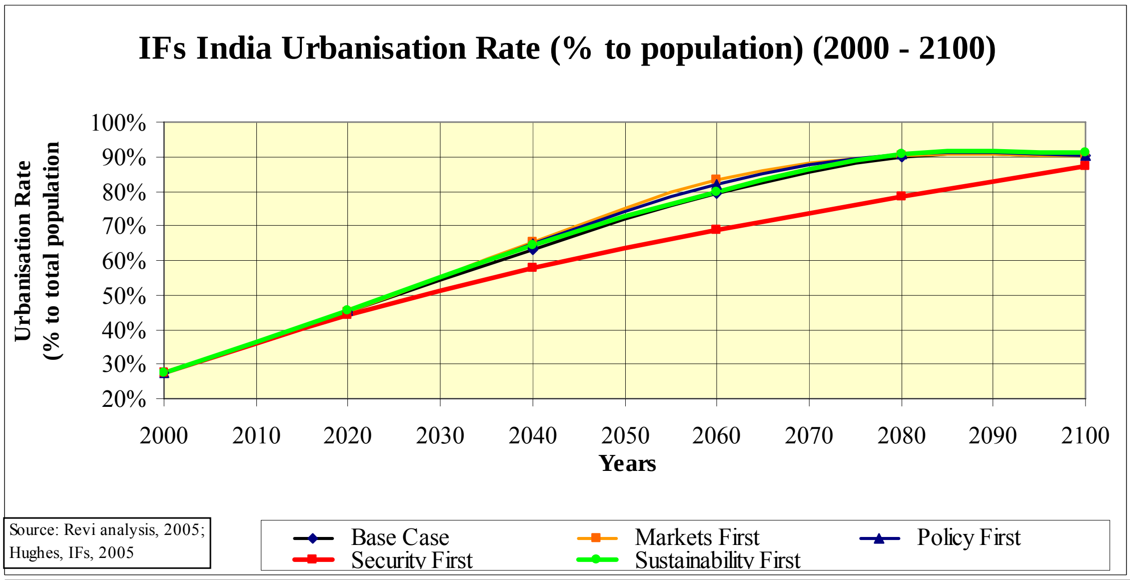
# Installed electric power capacity – South Asia 1971-2100

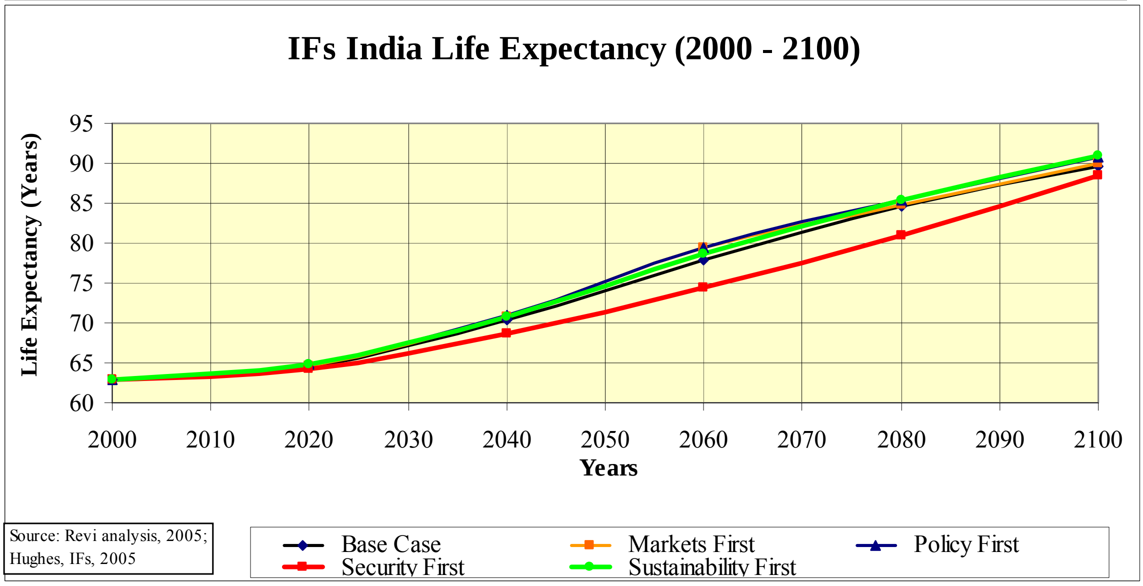


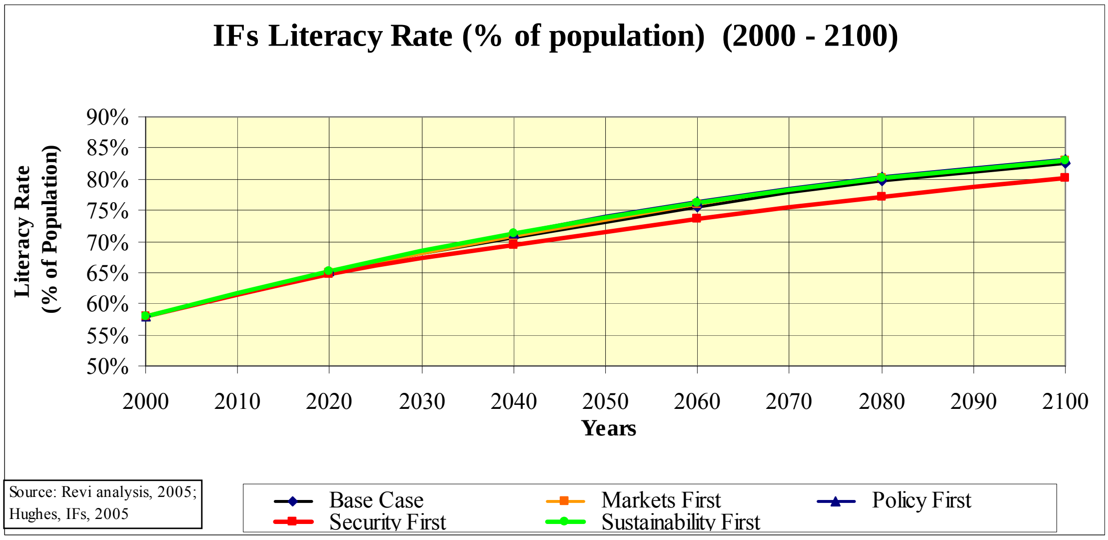

*Simulation of the primary energy consumption and production in South Asia for the high-growth high-tech scenario A1b (left) and the equity and environment oriented B1 scenario (right), as simulated with the TIMER-model. Notice the important role of traditional energy sources (MNP 2006)*

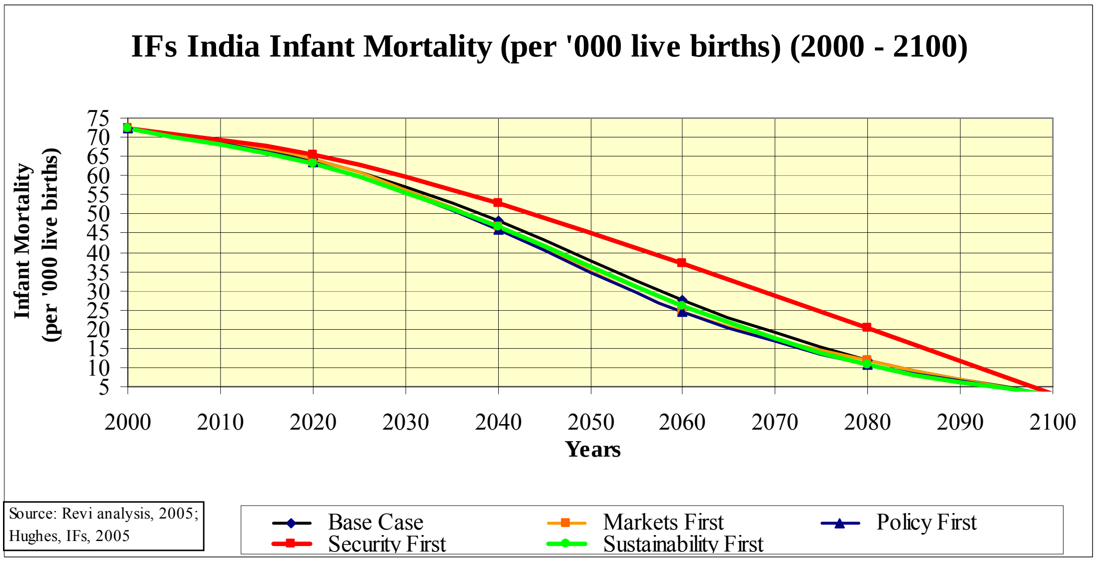
# Annex H Forward projections for India 2000-2100 with the IFs-model

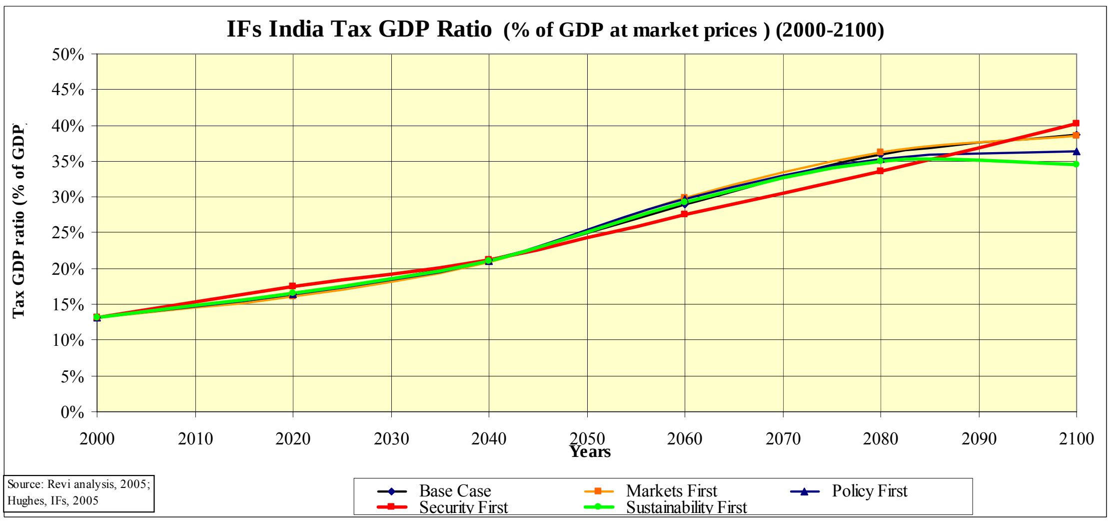


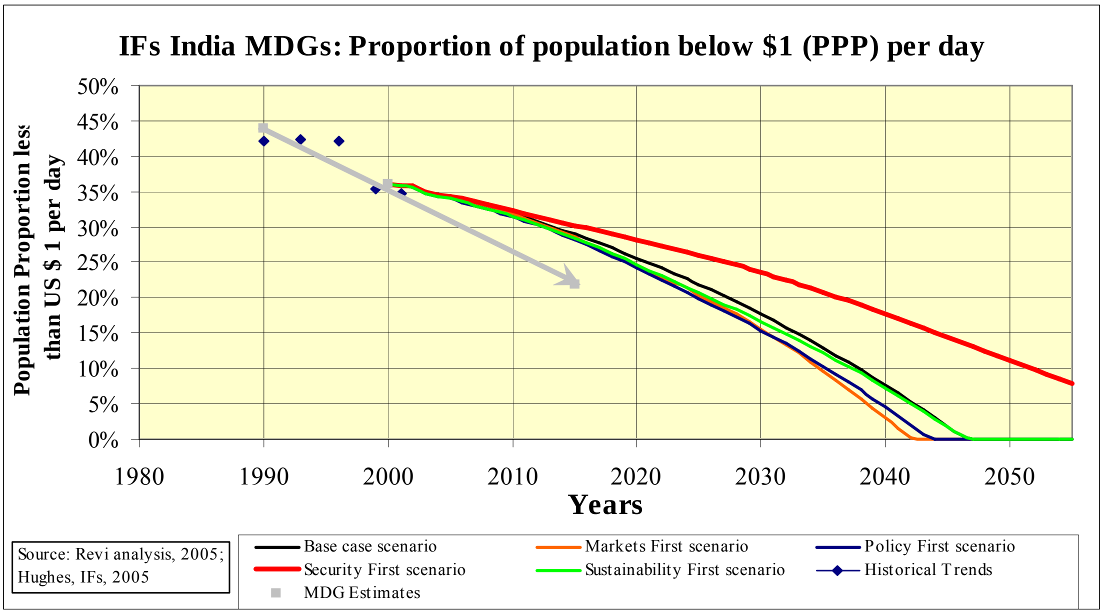



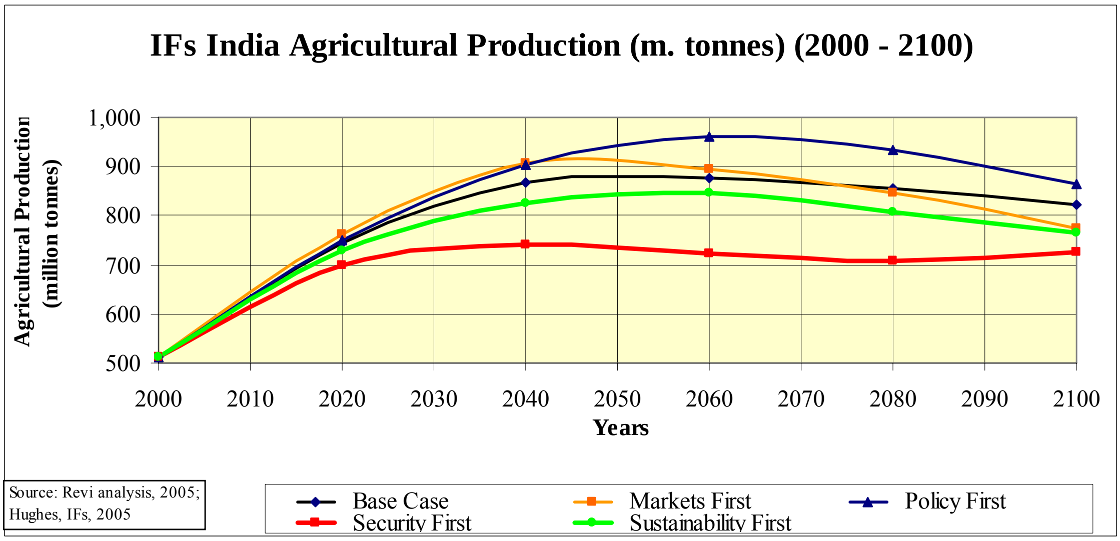



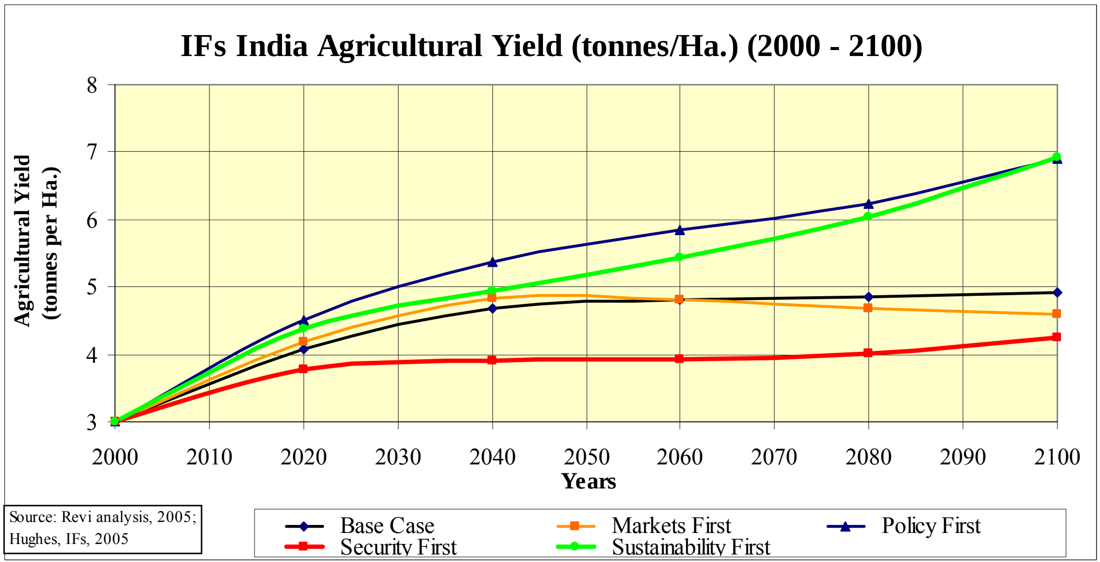

IFs Literacy Rate (% of population) (2000 - 2100)
Literacy Rate (% of Population)
90%
85%
80%
75%
70%
65%
60%
55%
50%
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Security First
Markets First
Sustainability First
Policy First

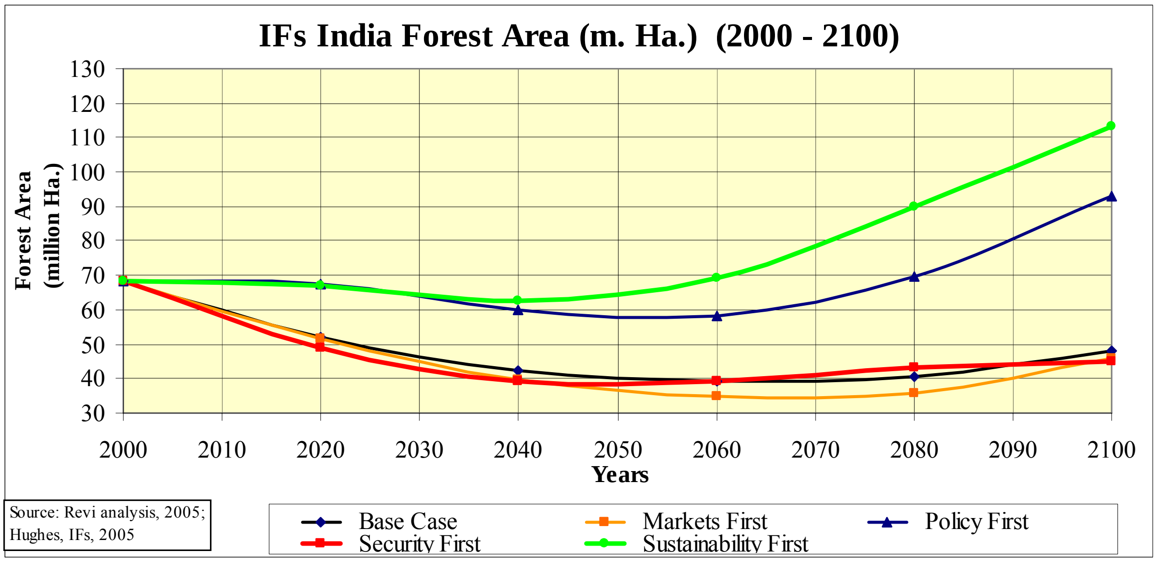

IFs India Infant Mortality (per '000 live births) (2000 - 2100)
Infant Mortality (per '000 live births)
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Security First
Markets First
Sustainability First
Policy First

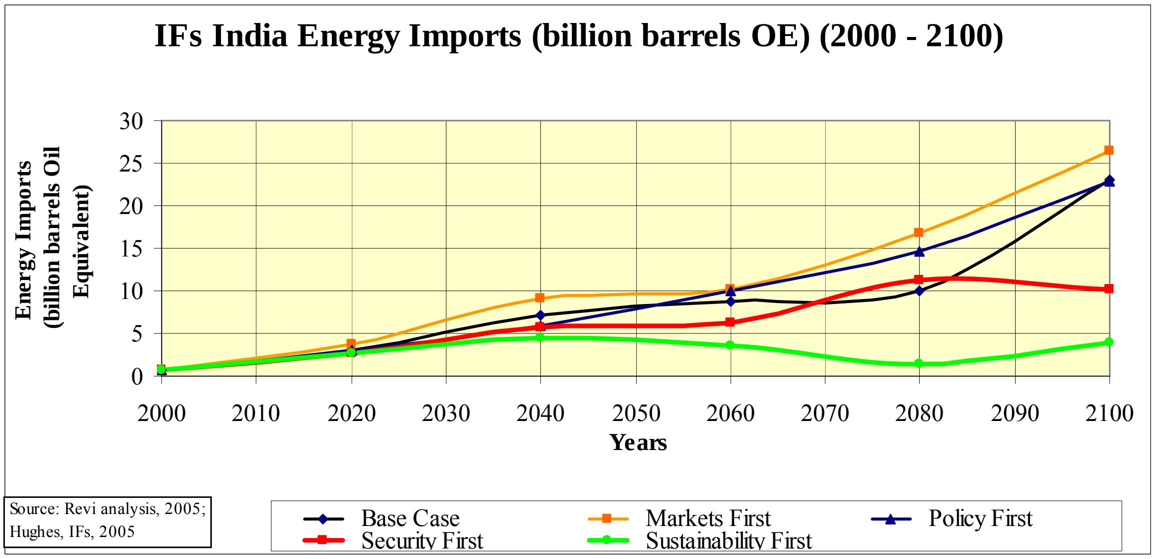

IFs India Tax GDP Ratio (% of GDP at market prices ) (2000-2100)
Tax GDP ratio (% of GDP
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Security First
Markets First
Sustainability First
Policy First

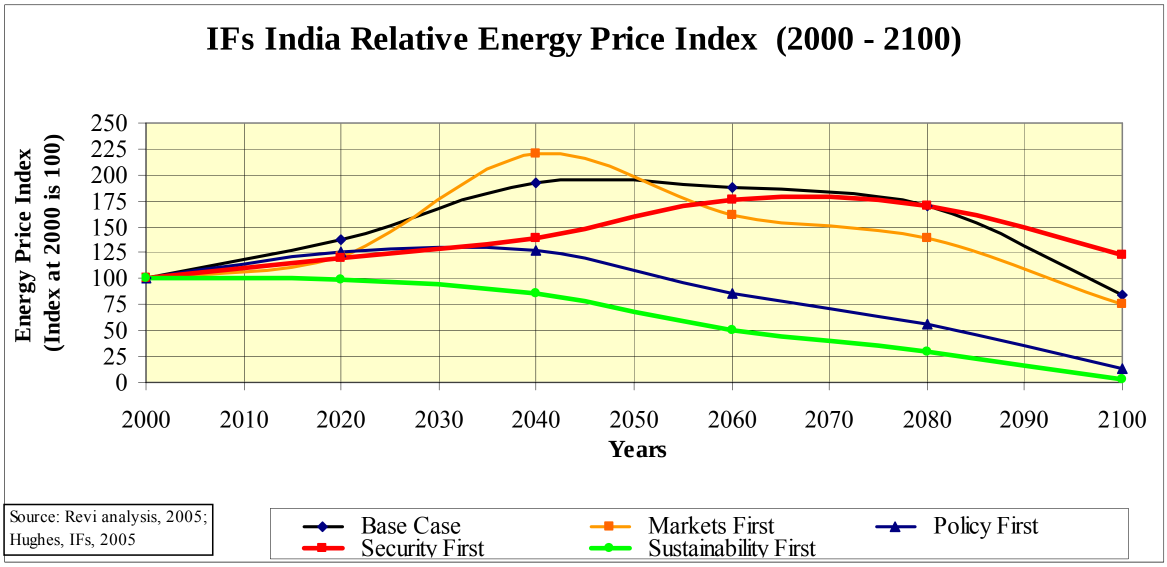

IFs India MDGs: Proportion of population below $1 (PPP) per day
Population Proportion less than US $ 1 per day
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
1980
1990
2000
2010
2020
2030
2040
2050
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base case scenario
Markets First scenario
Policy First scenario
Security First scenario
Sustainability First scenario
Historical Trends
MDG Estimates

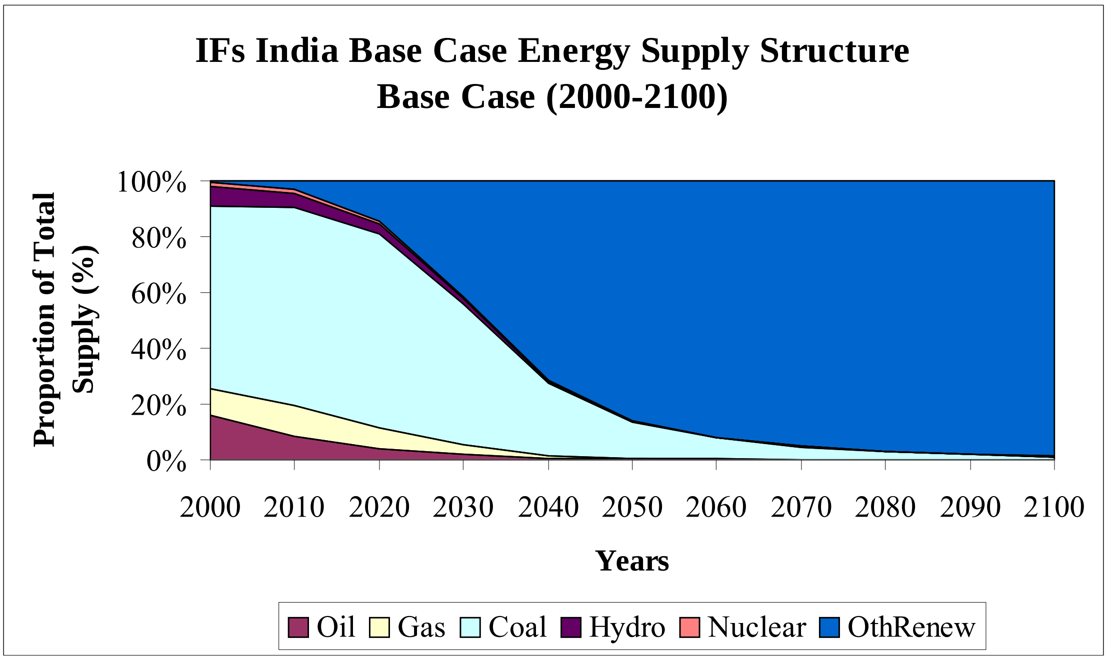

IFs India Agricultural Production (m. tonnes) (2000 - 2100)
Agricultural Production (million tonnes)
1,000
900
800
700
600
500
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Markets First
Policy First
Security First
Sustainability First

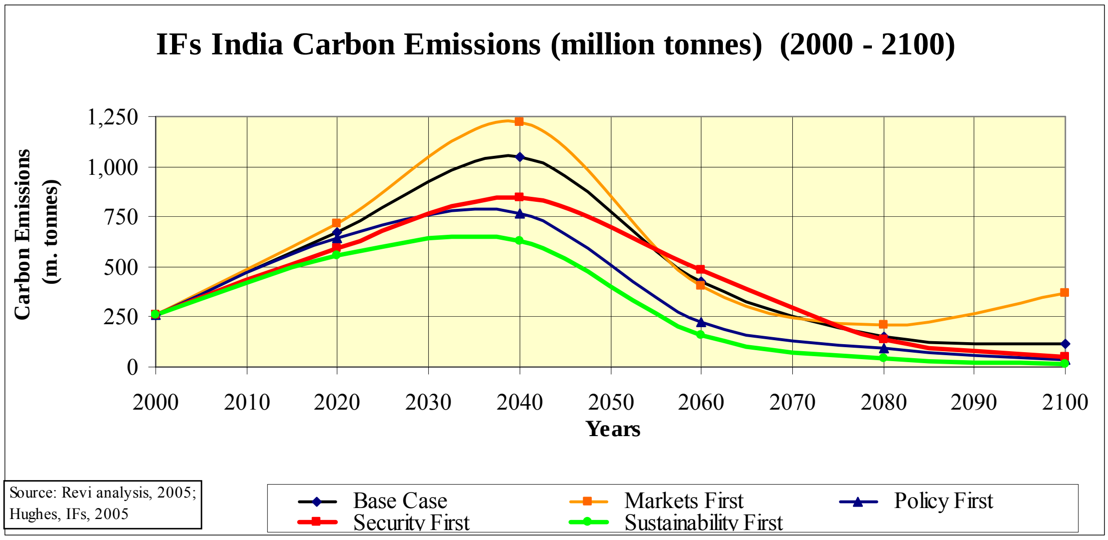

IFs India Agricultural Yield (tonnes/Ha.) (2000 - 2100)
Agricultural Yield (tonnes per Ha.)
8
7
6
5
4
3
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Markets First
Policy First
Security First
Sustainability First

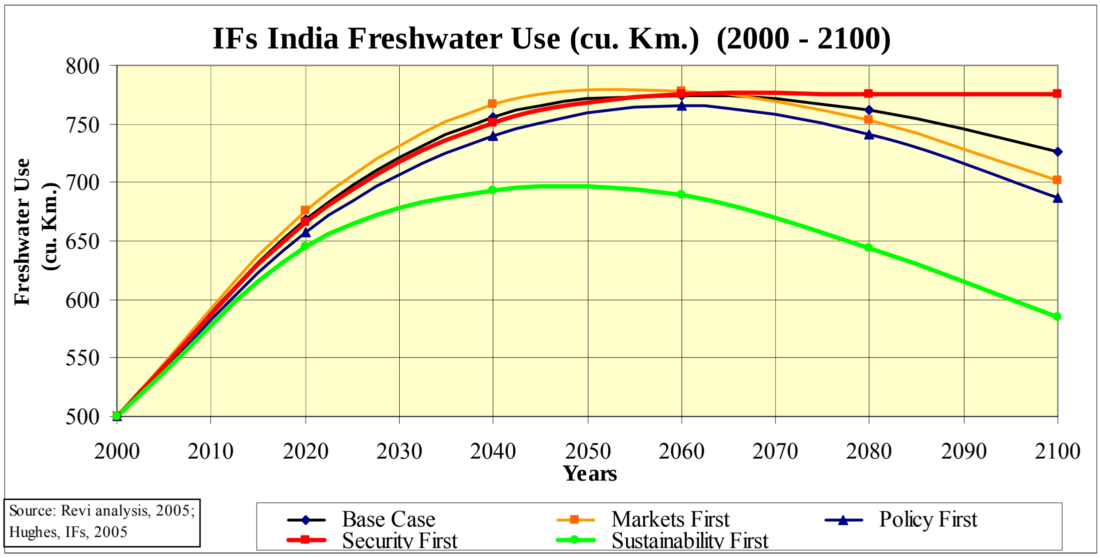

IFs India Forest Area (m. Ha.) (2000 - 2100)
Forest Area (million Ha.)
130
120
110
100
90
80
70
60
50
40
30
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Security First
Markets First
Sustainability First
Policy First


IFs India Energy Imports (billion barrels OE) (2000 - 2100)
Energy Imports (billion barrels Oil Equivalent)
30
25
20
15
10
5
0
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Security First
Markets First
Sustainability First
Policy First


IFs India Relative Energy Price Index (2000 - 2100)
Energy Price Index (Index at 2000 is 100)
250
225
200
175
150
125
100
75
50
25
0
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Security First
Markets First
Sustainability First
Policy First


IFs India Base Case Energy Supply Structure
Base Case (2000-2100)
Proportion of Total Supply (%)
100%
80%
60%
40%
20%
0%
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Years
Oil Gas Coal Hydro Nuclear OthRenew


IFs India Carbon Emissions (million tonnes) (2000 - 2100)
Carbon Emissions (m. tonnes)
1,250
1,000
750
500
250
0
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Markets First
Policy First
Security First
Sustainability First


IFs India Freshwater Use (cu. Km.) (2000 - 2100)
Freshwater Use (cu. Km.)
800
750
700
650
600
550
500
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years
Source: Revi analysis, 2005; Hughes, IFs, 2005
Base Case
Markets First
Policy First
Security First
Sustainability First