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Land use planning in India: Past and future

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Abstract: Research work in the field of land use planning in India is reviewed and important milestones such as development of Agro-Ecological Region map of the country, development of soil suitability criteria for different crops grown in the country, customized soil survey for a commodity of interest like rubber, land use plans implemented at watershed and village levels and suggested land use plans for different administrative units are discussed. The constraints in developing land use plans are non-availability of adequate, reliable hydro-climatic data, associated natural resource data and socio-economic data. Soil suitability criteria for crops need to be relooked after new advances. Hitherto unaddressed issues like assessing common property resources, water resources, pasture lands, village commons, NTFP and their role in LUP *etc*. are highlighted. Future areas of work like land resource inventory of the nation at 1:10000 scale and LUP priorities like mapping prime lands for agriculture, studying land use changes and their impact on water availability, refining soil suitability criteria, delineating management units for nutrient management *etc.* are spelt out. Development of protocol for data collection, its geo-referencing, economic evaluation of land and other recommendations are made for effective land use planning. In this regard, a dynamic information system depicting different categories of land use and crop grown on each parcel of land needs to be developed. Use of geo-spatial technologies is fast becoming an essentiality for managing conflicting land use demands. It is felt that decision support systems need to be developed for different management units such as watershed, panchayat, block, tahsil, district *etc.*

Introduction

Food and Agriculture Organization (FAO) de?ned land-use planning as the systematic assessment of land and water potential, land-use alternatives and socio-economic conditions in order to adopt the best land-use options (FAO 1996). Most of the research work in India and abroad has followed the frame work defined by FAO. In 2007, the FAO land evaluation framework concepts and methodological approaches have been revised and expanded, taking into account much more explicitly the different functions and services offered by land and soil, threats to sustainable land uses, and limitations ?nding its origin in economic and societal conditions (FAO 2007). However, the context of land use planning could vary widely with socio-economic conditions of the community or the country. In an agrarian economy like India, a tiny land parcel by western standards is often the only source of living for a rural family.

With 183 million ha area categorized as cultivable land and a population above a billion, India has less than 0.14 ha of cultivable land per person. Compared to highly populated China (0.08 ha/person), it seems to be better but comparable economy of Brazil has 0.37 ha/person asides greater area under forest (World Bank Report). The last decade has been a decade of land conflicts as numerous protests have been reported from different parts of the country. A subtle shift from fertility based demand for land to location based demand has accelerated price rise in the country and successive Governments have been forced to revise the land acquisition policies effected from time to time. The significant spurt in demand for land for different purposes is now causing rapid changes in the way lands are managed in the country where land is a scarce resource. This article is centered on the research in the field of land use planning in the country.

Land resources of India

India follows a mixed model of land ownership, wherein forest lands are owned and managed by the state and an ordinary citizen has no rights over these lands. The concessions accorded to the people living in and around forest include access to non timber forest produce, grazing rights in identified zones *etc*. On the other hand, agricultural lands are owned by individuals/citizens. The ownership rights however vary across federal states. Land use could be executed and managed by disparate agencies working with different objectives. Agricultural land use planning in India is thus mostly an academic exercise with limited advisory role. Supported by institutional mechanism and state regulations regarding forest lands on the other hand have led to significant increase in forest cover.

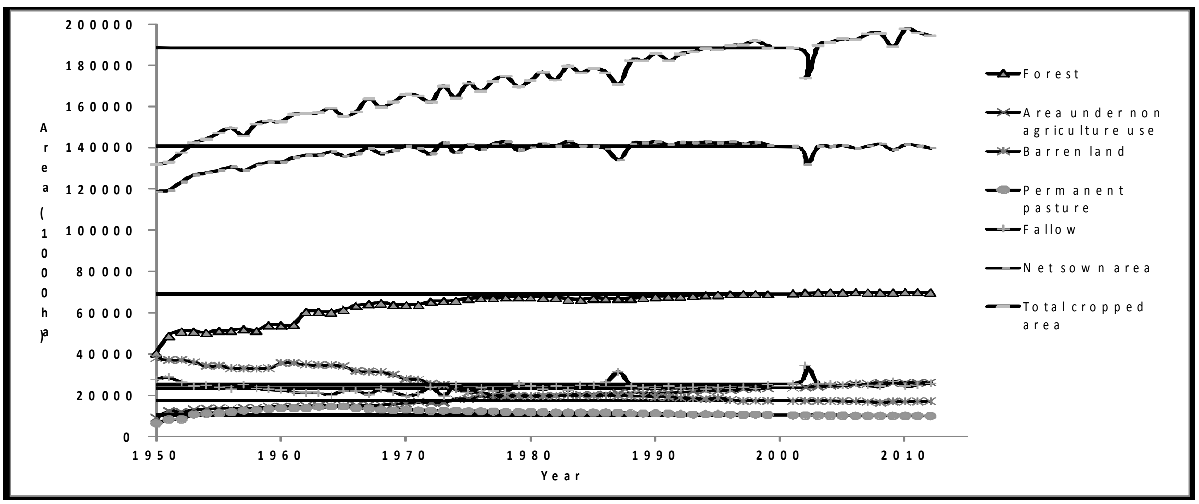

Fig.1. Land use changes in India
(*Source*: Indiastat http://www.indiastat.com/default.aspx)

Land use statistics of India since 1950 indicates some interesting patterns. Area under forest has increased from $40482x10^3$ ha in 1950 to $70007x10^3$ ha in 2012, which is a 72 % increase. Total cropped area has increased from 131893 $x10^3$ ha in 1950 to $194399x10^3$ ha in 2012, which is again a 47 % increase. However, the graph (Fig. 1) clearly depicts that the uses like forest, total cropped area, net sown area, permanent pastures *etc*. have plateaued after initial surge. Per capita land availability has decreased continuously from 0.87 in 1950 to 0.26 ha in 2011. It is apparent that the area under agriculture probably will remain unchanged or decrease with increased demand for land for other uses like habitation, infrastructure development, industry *etc*.

Current needs and future demands

Under the assumption of 3.5% growth in per capita GDP (low income growth scenario), demand for food grains (including feed, seed, wastage and export) is projected in the year 2020 at the level of 256 mt comprising 112 mt of rice, 82 mt of wheat, 39 mt of coarse grains and 22 mt of pulses (Agriculture Policy Vision 2020, Planning Commission). The demand for sugar, fruits, vegetables, and milk is estimated to grow to a level 33,77,136 and 116 mt respectively. The demand for meat is projected at 9 mt, fish 11 mt and eggs 77.5 billion. Future increases in the production of cereals and non-cereal agricultural commodities will have to be essentially achieved through increases in productivity, as the possibilities of expansion of area and livestock population are minimal. To meet the projected demand in the year 2020, country must attain a per hectare yield of 2.7 tons for rice, 3.1 tons for wheat, 2.1 tons for maize, 1.3 tons for coarse cereals, 2.4 tons for cereal, 1.3 tons for pulses, 22.3 tons for potato, 25.7 for vegetables, and 24.1

tons for fruits. The production of livestock and poultry products must be improved 61% for milk, 76% for meat, 91% for fish, and 169% for eggs by the year 2020 over the base year 1999. Average yields of most crops in India are still rather low (Paroda and Kumar 2000).

Keeping this in view, the land use plans have to be made for achieving higher productivity and sustainable food security.

Land use planning research in India

The land use planning research in India and abroad has been done mostly by soil scientists with expertise in soil survey. The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) is entrusted with research, training, correlation, classification, mapping and interpretation of soil information. Therefore work done in India is mostly confined to the research work by NBSS and LUP that could be broadly divided into four categories in a chronological order.

1. During the early years, zonation of the country based on length of growing period criteria was focused.
2. Development of soil suitability criteria for major crops of the country followed by crop experiments to evaluate the developed criteria including soil attributes
3. LUP at different planning levels/units like village, watershed, district based on soil distribution, topography and climate.
4. Customized LUP like identifying suitable area for commercial crops -rubber, tea *etc*.

1. Zonation of the country: Based on the concept of length of growing period (LGP) which is an index of crop production that considers soil moisture availability for the crop, the country was divided into 20 Agroecological (AER) regions. Four basic maps *i.e.* soil, physiography, length of growing period (LGP) and bioclimate are required to delineate agro-ecological regions (AER) (Sehgal *et al.* 1992; Sehgal *et al.* 1993) agro-ecological subregion (AESR) and agro- ecological zone at state and agro-ecological unit at watershed level. The criteria used at different levels of Agroecological zoning exercise are shown in Table 1.

Table 1. Criteria used for agro-ecological delineation

Level	Criteria used			
	Soil	Physiography	Bioclimate	LGP*
Agro-ecological sub-regions of India (60 AESR) (for resource planning at regional level).	Sub group association (1:1 m scale)	Sub division of major physiography	Arid/typic arid/hyper arid semiarid/ semi arid dry/semi arid moist sub humid/ dry/moist humid, perhumid	<60 (with 30 days interval) to >330 days
Agro-ecological zones at state level (for resource planning at state level)	Soil family association (1:250,000 scale)	Landform	Bioclimate computation based on subdivision level rainfall data	LGP isolines with 15 days interval
Agro-ecological unit at district level (for resource planning at district level)	Soil series association (1:50,000 scale)	Geomorphic Unit	Bioclimate computation based on rainfall at block level	LGP isolines with 7 days or 10 days interval
Agro-ecological unit at watershed level	Soil phase (1:5,000 scale)	Details of geomorphic units	Effective rainfall at unit level	LGP based on AWC (soil unit)*

Source: Velayutham *et al.* 1999.
*LGP= Length of Growing Period; AWC= Available Water Capacity. *<90 days: Feasible for single short duration crop; 90-150 days : Suitable for one medium duration crop or single short duration crop plus relay crop; >210 days : Feasible for double cropping

The climatic regions in India with the length of growing period are summarized in Table 2.

Table 2. Agro-ecological regions

Sr. No.	Region	LGP (days)	Area (% of TGA)	AER
1.	Arid	<90	16	1,2,3
2.	Semi-arid	90-150	36	4,5,6,7,8
3.	Sub-humid	>150	32	9,10,11,12,13,14
4.	Humid/perhumid	>270	10	15,16,17
5.	Coastal	Varying	6.5	18,19

Source: Sehgal *et al.* 1995.

Bioclimate and LGP were superimposed on soilscape to delineate the AER units. This facilitated Planning commission and Government of India in taking number of development decisions. However, the initial work was based on five LGP classes. Realizing the limitations of crop diversity and narrower LGP, the AERs were further subdivided into 60 sub-regions. Utility of sub-zonation has been demonstrated in estimating carbon soil carbon status and available potassium in Indo Gangetic Plains and Black Soils Region of the country.

More than 50 percent of the country has semi-arid to arid climate and needs to be supplemented with irrigation for agriculture production. Nearly 42 percent of the country has LGP above 150 days in a year where rainfed agriculture is supported by available soil moisture.

Recently (Mandal *et al.* 2014) modified the AESR maps based on newly acquired soil resource database and revised LGP class with greater emphasis on soil quality parameters linked with crop performance of the two major food production regions of India, namely Indo Gangetic Plains (IGP) and Black Soil Region (BSR). 17 AESRs of IGP and 27 AESRs of BSR were re-delineated respectively, into 29 and 45 sub-regions. The AESR revision opens a new possibility of linking the potential of natural resources and crop performance for better and pragmatic crop use planning.

2. In the next stage soil suitability criteria were developed for major crops of the country. This work was essential to evaluate if the land was being utilized for a crop with scientific rationale. This exercise involves rating of the soil site parameters as highly suitable (S1) with slight limitations, moderately suitable (S2) with moderate limitations, marginally suitable (S3) with severe limitations and unsuitable (N). The land and soil characteristics considered in evaluation studies are enlisted in Table 3.

Table 3. Important land and related soil characteristics

Land quality	Land/soil site characteristics
Temperature and solar energy for plant growth	Temperature (max and min), Sunshine hours, length of day
Moisture availability during crop period	Rainfall, PET, Soil depth and texture, relative humidity
Root development and anchorage	Soil depth, structure, texture in root zone, hard pans
Nutrient availability in root zone	Organic matter, CEC, base saturation, NPK status, pH
Sensitivity to toxicity	pH, salinity, sodicity, $CaCO_3$, Al and heavy metals
Workability and management	Slope, surface stoniness/rockiness, moisture retention

For evaluating soil suitability for an intended crop, few or all of these characteristics may be included in a set of criteria. Later, climate of the soil unit is compared with the crop requirements, then soil and physiographic properties are examined to meet crop requirements. The criteria are discussed amongst a group of experts to arrive at consensus. An example of such exercise is presented below in Table 4. Soil suitability criteria for two cereal crops, rice, wheat and one important fibre crop-cotton are shown in Table 4, 5, and 6. These criteria are usually dynamic and are revised with advancements and knowledge of a particular crop and soil.

Table 4. Soil-site suitability criteria (crop requirements) for rice

Soil-site characteristics		Rating			
		Highly suitable	Moderate-ly suitable	Marginally suitable	Not suitable
Climatic regime	Mean temperature growing season (^{o}C)	30-40	35-38 21-29	39-40 15-20	>40 <15
	Total Rainfall (mm)	1110-1250	900-1100	750-900	<750
Land quality	Land characteristics				
Oxygen availability to roots	Soil drainage (class)	Imper-fectly drained	Modera-tely drained	Well drained; somewhat excessively drained	Excessive ly drained
	Free from flooding (duration – month)	>4	3-4	2-3	
	Depth of water (cm)	<10	10-20	>20-40	>40
Nutrient availability	Texture* (class)	c, sic, cl, sicl, sc	scl, sil, l	sl, ls	s
	pH (1:2.5)	5.5-6.5	6.4-7.5 4.5-5.4	7.6-8.5	>8.5 <4.5
	$CaCO_3$ in root zone (%)	<15	15 to 25	25 to 30	>30
Rooting condition	Effective soil depth (cm)	>75	51 to75	25 to 50	<25
Soil toxicity	Salinity (EC satura-tion extract) (ds/m)	<3	3 to 6	6 to 10	>10
	Sodicity (ESP) (%)	<15	15 to 40	40 to 50	>50
Erosion hazard	Slope (%)	0 to 1	1-3	3-5	>5

Source: Naidu *et al*. (2006) Flooding is considered for rainfed rice.
Note: s-sand; ls-loamy sand: sl-sandy loam; scl-sandy clay loam; cl-clay loam; sil-silt loam; l-loam; sic-silty clay; sc-sandy clay; c-clay.

Table 5. Soil-site suitability criteria (crop requirements) for Wheat

Soil-site characteristics		Rating			
		Highly suitable	Moderate-ly suitable	Marginally suitable	Not suitable
Climatic regime	Mean temperature growing season (^oC)	20-25	26-28 18-19	29-34 14-37	<14 >34
Land quality	Land characteristics				
Moisture availability	Length of growing period (LGP) (days)	>150	120-150	90-120	<90
Oxygen availability to roots	Soil drainage (class)	Well drained to modera-tely well drained	Imperfectly drained	Poorly drained	Very poorly drained Excessive ly drained
Nutrient availability	Texture* (class)	l, cl, sil, scl	sc, sic. c, ls, sicl, sl,	c+(45-60%)	s, c++ (>60%)
	pH (1:2.5)	6.5-7.5	7.6-8.5; 5.5-6.4	8.6-10; 4.5-5.4	<4.5; >10
	OC (%)	0.6-0.7	0.5-0.6	0.3-0.5	<0.3
Rooting condition	Effective soil depth (cm)	65-100	65-50	50-25	<25
	Stoniness (%)	<15	15-30	>35	
Soil toxicity	Salinity (EC satura-tion extract) (ds/m)	<4.0	4.0-6.0	>6.0	
	Sodicity (ESP) (%)	<15	15-30	30-40	>40
Erosion hazard	Slope (%)	<3	3-<5	5-10	>10

*C+= Clay(45-60%), C++=>60%.

Such criteria have been developed for all major crops grown in the country. During an early part of the new millennium, National Agriculture technology Project (NATP) was taken up by the bureau. Soil suitability criteria for five different agro-eco systems were developed as shown in Table 6.

Table 6. Soil suitability criteria for growing season

Soil-site characteristics		Rating			
		Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Climatic regime	Mean temp. in growing season (°C)	20-30	31-15	<19 >35	--
	Mean max. temp. in growing season (°C)	--	--	>36	--
	Mean min. temp. in growing season (°C)	--	--	<19	--
	Mean RH in growing season (°C)	60-90	--	<50	--
	Total Rainfall (mm)	700-1000	500-700 1000-1250	<500 >1250	--
	Rainfall in growing season (mm)	600-950	450-600	<450	--
Land quality	Land characteristics				
Moisture availability	Length of growing period (days)	180-240	120-180	<120	--
	AWC (mm/m)	200-250	125-200	50-125	<50
Oxygen availability to roots	Soil drainage (class)	Well to moderately drained	Imperfectly drained	Poor to somewhat excessively drained	Stagnant/ excessive
	Waterlogging growing season (days)	1-2	2-3	3-5	>5
Nutrient availability	Texture* (class)	sic, cl	sicl,cl	si, sil, sc, scl, l	sl, cm, s, ls
	pH (1:2.5)	6.5-7.5	7.6-8.0	8.1-9.0	>9.0 <6.5
	$CaCO_3$ [cmol(p+) kg]	>55	50-55	30-50	<30
	BS (%)	>80	50-80	35-50	<35
	$CaCO_3$ in root zone (%)	<3	3-5	5-10	10-20
	OC (%)	>1.00	0.75-1.0	0.50-0.75	<0.50
Rooting condition	Effective soil depth (cm)	100-150	60-100	30-60	<30
	Stoniness (%)	<15	15-25	25-50	50-75
	Course fragments (Vol.%)	<5	5-10	10-15	15-35
Soil toxicity	Salinity (EC satura-tion extract) (ds/m)	2-4	4-8	8-12	>12
	Sodicity (ESP) (%)	5-10	10-15	20-30	>30
Erosion hazard	Slope (%)	1-2	2-3	3-5	>5

Source: Naidu *et al*. (2006).

Table 7. Details of soil series identified and LUP work conducted under NATP

Agro-eco System	No. of Soil Resource Maps generated	No. of Soil Series	No. of crops -Soil suitability criteria developed	No. of LUP demonstrations
Rainfed	16	135	-	932
Coastal	10	64	66	105
Arid	10	23	34	34
Hill & Mountain System	11	59	10	
Irrigated	11	28	18	

Source: NATP Report (2004).

Simultaneously, different land use options were also experimented in these five agro-eco systems. For example, in the coastal eco-system, the land use options identified on the basis of bio-physical and socio-economic resources included plantation of cashew, casurina and palmyra on coastal sand, rubber and pepper plants on foothills and agricultural crops like paddy, pulses, cotton and vegetables on coastal alluvium. In arid zone, less water requiring crops like mustard, cumin and isabgol were introduced and evaluated.

The research efforts in general identified three broad categories of state intervention 1) introduction of new crops and livestock components based on soil suitability and potential for enhanced agricultural productivity 2) introduction of new varieties commiserate with the soil information/properties and 3) adoption or changes in land management techniques. These findings facilitated the planners to assess the potential of different crops and possible changes in land use in different agro-eco systems. Realizing the need to suggest possible changes in crop planning, at micro-level like village as a planning unit, research emphasis also included experimentation at farmer and village level.

3. In a concurrent as well as subsequent effort, the developed soil suitability criteria were evaluated in farmers' field and refined. Land use plans were developed for smaller units like village, watershed, district *etc*. The bureau has implemented soil based land use plans for number of villages in the country and demonstrated that agricultural productivity is intrinsically linked to soil status and enhanced productivity can be achieved with scientific utilization of soils. Efficacy of LUP has been demonstrated (NBSS and LUP 1982; Hajare *et al.* 2002; Hirekerur *et al.* 1986; Ramamurthy *et al.* 2007) on 2180 ha area of seven different villages.

Few important findings (NATP 2004) are listed below:

- In Vidarbha, (Maharashtra) soil depth, plant available water capacity, texture, exchangeable magnesium, cation exchange capacity and slope were major attributes influencing soybean yield.
- The high clay content, $CaCO_3$ and poor drainage of deep shrink-swell soils limit the productivity of orange in Nagpur District. The shallow soils although have limitation of solum but do not pose problem of root development and hence under proper agro-management, the productivity of these soils can be enhanced.
- Clay content and drainage of the soil are the dominant characteristics contributing towards banana yield, followed by coarse fragments, $CaCO_3$, organic carbon content, pH, exchangeable Ca and Mg.

Oilseed crops (suitability evaluation)

- District Junagarh in Gujarat, has 69.5% area under soils that are moderately suitable for groundnut cultivation. Salinity, sodicity, stoniness and depth are the main constraints.

- Similarly, Rajkot district has 65% area covered by moderately suitable soils for growing groundnut.
- Bharatpur district, Rajasthan has 60.3% moderately suitable, 29.7% highly suitable and 10.1% marginally suitable soils.

Rainfed agro-eco systems

- A total of 932 alternative land use options were /demonstrated over 603 ha at 1294 sites on 132 soil subgroups on different toposequences in rainfed agro-ecosystem in 16 micro-watersheds. This provided the much needed land use diversification from the traditional rainfed land utilization.
- Despite deficit rainfall (2002-2004) in these rainfed systems, the interventions like critical dryland practices, contingency crop plans, and alternate land use systems increased the yields by 30 – 50 % and in a few cases it doubled.

Coastal region

The marginal farmers in coastal region were advised land use change through (a) introduction of new crops / animal components (b) introduction of new varieties and (c) development of suitable land management practices.

Hill and mountain agro-ecosystem

- Introduction of location specific improved varieties of *kharif* and *rabi* crops in different watersheds of the system increased the yield by 1.28 to 1.72 times and 1.24 to 1.62 times with low input level under rainfed conditions. Cash crops *viz.* ginger, tumeric and colocasia introduced in the watershed produced 10575, 7890 and 11895 kg/ha yield, respectively. The increase in the yield of various crops resulted in wide impact for their adoption and acceptability by the stakeholders. Alternative land use *i.e.* horticulture including fruit plants like mango (Dashahri), Guava (L-49) and citrus (Eureka) were introduced.

Paradigm shift in land use planning

The last decade has witnessed a major change in the way land use plans are prepared. The Indian experience showed that farmers do not adhere to the land use plans or grow crops according to soil suitability irrespective of the location and findings of soil suitability studies. The reasons for non-compliance were varied, for instance socio-economic compulsions (market availability, family needs, cash crop), management issues (spatial distance from village, labour availability, land size), resource availability (credit, tools). Further, top-down approach adopted by the researchers was not readily acceptable.

Therefore, inclusive land use planning was emphasized during the recently concluded National Agriculture Innovation Project (NAIP) implemented by the bureau (NAIP 2009 to 2014). Moreover, in addition to the soil resources, common property resources such as community water tanks, pasture lands, community lands, Non Timber Forest Produce (NTFP) were also included for arriving at a land use plan for a village. Crop diversification was also promoted with active participation of the farmers. Landless villagers participated in the process as they had stakes in common property resources.

For example, in a study undertaken in Gondia district (Maharashtra), land use planning in tribal village primarily aimed at optimal use of soil and water resources and use of common property resources especially for landless villagers. Community nursery utilized available water in organized way and facilitated early transplanting of rainfed rice that led to early harvest with 50 % increase in yields. The farmers realized mean additional income of Rs. 14,525/hectare (Table 8). It also opened new possibility of *rabi* crop raised on residual soil moisture (Fig. 2). The system has implications for 11.6 million ha. rainfed paddy area of the country. A farming system of rice-utera linseed – NTFP was developed to provide livelihood requirements.

Table 8. Rice yield in Gondia clusters before and after soil based land use during 2009-14

Year	(q/ha)	Area (ha)	Total Yield (q)	Income (Rs/ha)
2009-10	29.8	66.8	1990.64	35760
2010-11	27.8	181.2	5037.36	33360
2011-12	20.1	212.6	4273.26	24120
2012-13	28.4	240	6818.00	34080
2013-14	23.3	300	7005.00	30355
Mean	25.88	200.12	5024.85	31535

Source: NAIP (2014). *Baseline 16.2 q/ha—income Rs.17000/ha (Before soil based interventions)*

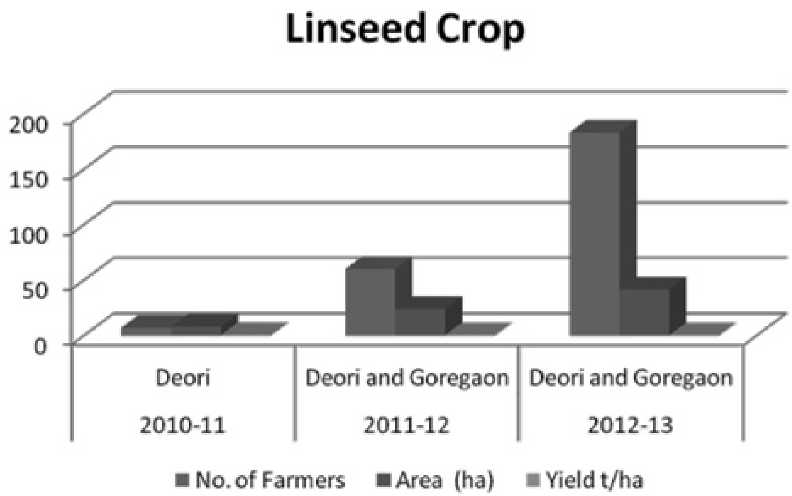

Fig.2. Linseed production in project clusters

In another participatory land use planning experiment conducted in Dhule district of Maharashtra, soil suitability for the onion crop in the district showed that it could be grown in approximately 1900 km^2 land (Fig. 3). Field trials also suggested that the onion crop could achieve higher economic returns (Rs. 100000 per ha).

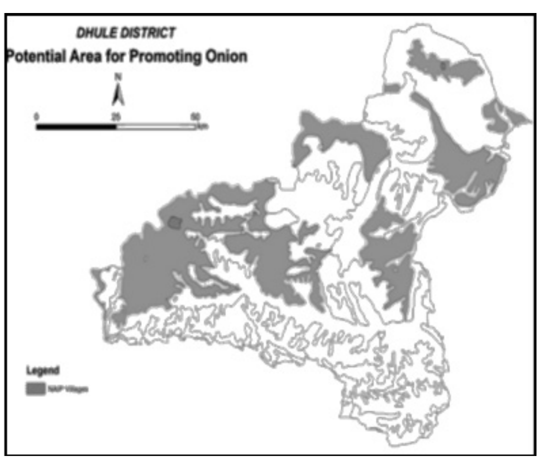

Fig. 3. Soil suitability for growing onion crop in Dhule district (Source :NAIP 2014)

Hitherto land use plans were prepared on an assumption that the agricultural crops will be raised on rainwater. Inclusion of farm ponds in planning process introduced the management of water resources for the first time in an experiment (Fig.4) conducted at Bali Island. Results showed that utility of farm ponds varied with Land Management Units (LMU). It implies that development of water resources need to be linked to soil resources. For instance, in LMU1 it enhanced the income from Rs. 2300-34400; Rs.3100-47800 and Rs.4500-68900, respectively and generated employment to the tune of 285, 405 and 600 man days respectively.

Fig. 4. Changes in land use before and after soil based interventions in Bali Island (*Source*: Annual Report NBSS and LUP 2014)

It is notable that all implementation of land use plans have been restricted to villages or cluster of villages with very limited geographical extent. Execution of land use plan for relatively bigger administrative/management units like block, tehsil or district is not feasible for a research purpose due to host of reasons like lack of institutional mechanism to enforce it, mixed model of land ownership followed in the country wherein farmer can at best be advised about the crop to be grown, lack of legal provisions *etc*. The district level land use planning has thus been restricted to preparation of plans and then leaving implementation to the administrators and line departments.

Specific response studies: During the last decade India witnessed a major gain in cotton productivity. While the area under this crop increased from 8.73 million ha to 11.55 million ha, the productivity increased from 308 kg/ha in 2001-02 to 552 kg/ha. (http://cotcorp.gov.in/statistics.aspx) in 2013-14 (Fig. 5). Intriguingly the decade has also seen abnormally high rate of suicides by cotton farmers in the country. Different reports carry different numbers but all reports agree that it is a national concern and thousands of farmers are ending lives every year. The federal state of Maharashtra is one of the major cotton growing regions and also a hub of unfortunate suicides. The bureau evaluated soils grown to cotton, maize and gram in a few villages. In one of the villages located in Aurangabad district (Table 8) 73 land parcels grown to cotton were evaluated for cotton suitability. It was observed that more than 40 % farmers cultivated cotton in marginally or unsuitable soils. In comparison to cotton, crops like maize or gram were grown to unsuitable soils to lesser extent. Mitigation measures thus could include adoption of better suited crops

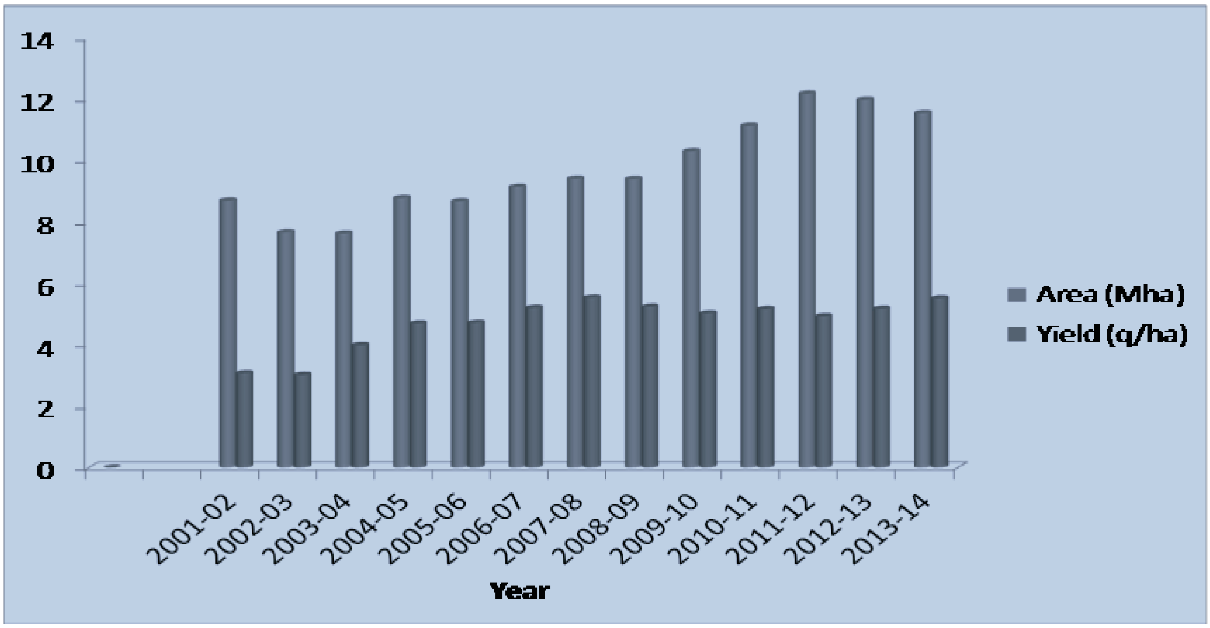

Fig.5. Area and productivity of cotton in India since 2001-02
(*Source*: http://www.indiastat.com/default.aspx)

Table 8. Yield of three different crops in soils of varied suitability

Crop		Highly suitable	Moderately suitable	Marginal suitable	Currently not suitable	Perma- nently not suitable
		(S1)	(S2)	(S3)	(N1)	(N2)
Cotton	No of farmers	5	38	4	5	21
	Yield	14	10	7	5	4
Maize	No of farmer	17	29	22		2
	Yield (q/acre)	28	20	14	-	10
Gram	No of farmers	18	29	26	-	2
	Yield (q/acre)	9	7	6	-	2

Source: NAIP (2014).

Asides these soil suitability studies for different crops, customized LUP like identification of suitable areas to promote rubber plantation in Kerala provide shining example of how state's intent and scientific LUP can change make a significant contribution to the well being of the stakeholders and national economy. It also demonstrates need for institutional mechanism to implement LUP for different units of planning.

Recent advances/use of modern tools in LUP

Soil survey has been modernized with the advent of remote sensing equipments and tools in India. Interactive Decision Support System (DSS) for district land use planning is a recent development. Interactive DSS assists land managers at district level for land/resource allocation. It allows user to asses/view soil information on 1:50,000 scale. Contingency plan (for drought) is also embedded into the system. Interaction with user groups (state officials) indicate that they are more interested in contingency plans.

Technological advances are also aiding hitherto difficult embedding of multi scale data and simulating different scenarios of land use and agricultural productivity. Under National Agriculture Innovation Project (Component 4) based on saturated hydraulic conductivity (sHC) database and length of growing period estimation, AESRs of IGP were modified from the existing 17 to a total 29 units. These modifications were accomplished using tools in GIS platform, climate data and expert opinion. Using district-level rice yield data, rice-growing areas in the IGP were divided into four regions such as low, medium, medium high and high representing areas with rice yield of < 1000, 1000–2500, 2500–4000 and > 4000 kg ha–1 respectively. These assessments show that nearly 33% area produces medium high to high category yields, while medium level yield is observed in 63% of the total rice-growing areas (Patil *et al.* 2014). Since the data on sHC were not readily available, pedotransfer functions were developed (Tiwari *et al.* 2014) for estimating the same for the soils of two food-growing zones of India (the Indo-Gangetic Plains (IGP) and the black soil region (BSR). In another study (Venugopalan *et al.* 2014) Infocrop model could satisfactorily capture subtle differences in soil variables and weather patterns prevalent in the Bench Mark locations spread over 16 agro-ecological sub-regions (AESRs) resulting in a wide range of mean simulated rainfed cotton yields (482-4393 kg ha^{-1}). These studies established applicability of modern tools in managing natural resources.

Constraints of LUP

The work discussed so far veered around the four major themes of research. It is pertinent to note that there have been problems, shortfalls, constraints *etc.* For instance, the Bureau was initially involved in doing district level soil surveys and the traditional soil survey reports would contain major 4 maps:

1. Physiography Map
2. Soil Map – Detailed Legend
3. Present Land Use – based on Soil Mapping Unit
4. Suggested Land Use - based on Soil Mapping Unit (SMU).

'Soil Mapping Unit' was the minimum polygon as the base for suggested Land Use and this was in the form of Association. The planner could get easily confused as the same SMU would be recommended to grow rice and sorghum, totally different genre of crops.

Further, soil suitability criteria developed by the bureau required refinement. The developed criteria were used for preparing Suitability Maps from the data on 1:250,000 scale for the all the states. There were, however, problems in interpretation as the suitability was found to be similar for certain types of crops (Fig. 6) *e.g.* areas with highly suitable soils for wheat in Bhopal district were also found to be highly suitable for gram though the crop water requirements differ substantially. The scale limitation on 1:25,000 and non-availability of ancillary data like water availability, socio-economic data for growers/cultivators caused inadequate acceptance of the recommended LUP

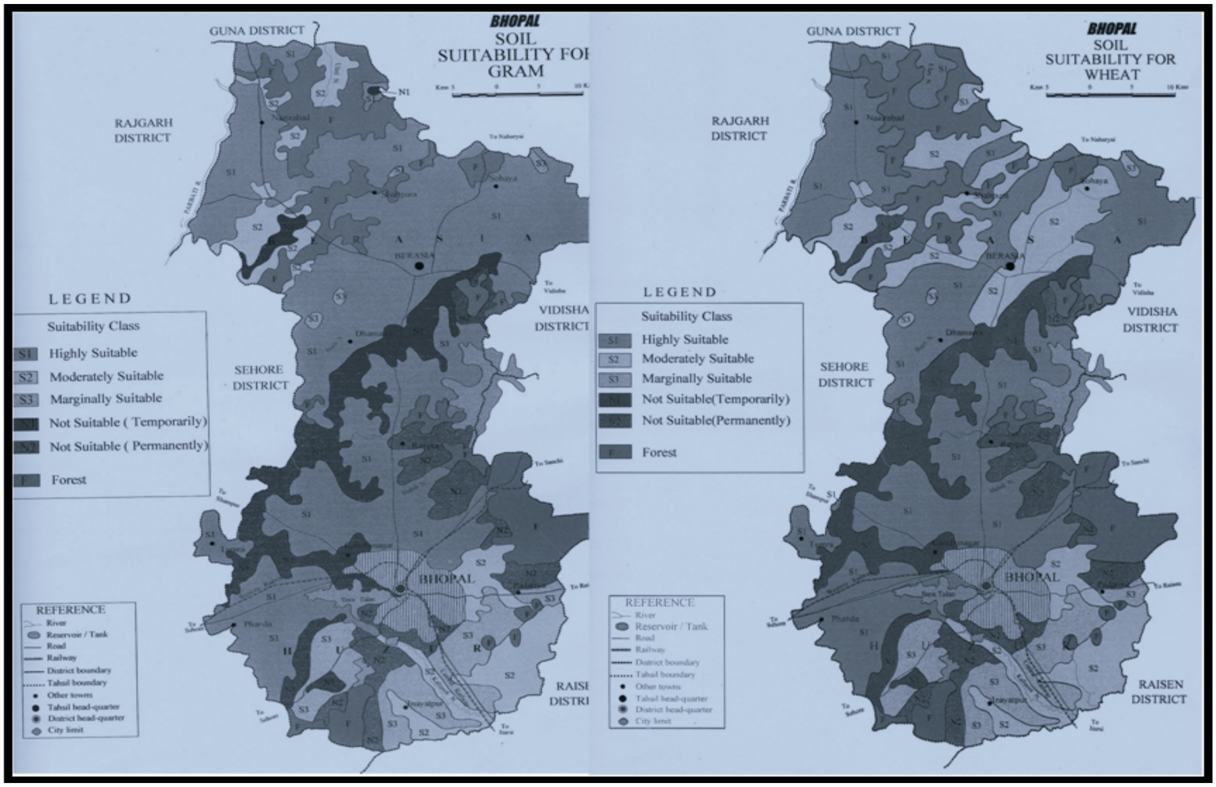

Fig. 6. Soil suitability for Gram and Wheat crop in Bhopal district
(Source: Tamgadge *et al.* 1999)

In fact, non-availability of adequate, reliable hydro-climatic, associated natural resource data and socio-economic data, an essential prerequisite for LUP is a major constraint. Though, increasing amount of data is now being collected, the scale, accuracy and availability continues to be an impediment. The union and federal Governments in India have not formed institutions to plan or implement land use decisions. Local Governments such as village councils though empowered to take decisions, cannot influence plans to discernible extent mostly because their powers are limited to use of village commons such as pasture lands, water tanks *etc*. However, it is not the lack of institutions but the lack of linkages between different development departments and institutions that appears to be the main hurdle in formulation of effective land use plans. For instance, clearance of proposal to build a water reservoir by irrigation or water supply department in area owned by forest department could take years because of the processes and multi-point checks that the proposal has to undergo. It may not be advisable to create specialized institutions as strengthening of existing structure through sensitizing, imparting skills, raising awareness level and better coordination that would enhance the utility of land use plans prepared with scientific rationale.

Land use planning is a specialized work that requires a set of skills that need to be acquired. Practical training of land use planners, administrators, researchers, decision makers is very limited. Land acquisition conflicts witnessed during the last decade bear testimony to the fact that inadequate information, lack of skills, lack of co-ordination and well defined policy *etc*. are the major contributing factors. It also underlines the necessity of economic feasibility and social acceptability of land use decisions.

Research for land use planning requires enhanced field investigations and a large variety of tools such as: Information Management, System Analysis, Decision Support Systems, Multicriteria Analysis, Geographic Information Systems, Remote Sensing, Computer Image Analysis, Sensors, Modeling Technique, Neural Network Technology, Land Evaluation *etc*. All these tools have to be considered under a broad and integrated approach related to food and other agricultural commodity production, rational land use planning, water saving, resource conservation, environmental impacts and socio-economic effects (Riveira and Maseda 2006). Given these complexities, it is obvious that land use planning at local level under the broader framework at state or country level is an appropriate approach as it is indeed difficult to conceive a local plan for a remotely connected centralized or apex agency.

Need for a new approach

The potential of land for various uses depends on both biophysical and socio-economic conditions. However, studies in India and abroad have been restricted to evaluation of soils, terrain and climate for intended and existing land uses. Evaluation of physical environment followed by socio-economic analysis is a rarity primarily due to difficulties in assessing simultaneously the impact of diverse conditions, institutional and legal aspects. Moreover, evaluation of physical environment is also limited. For instance land use plans are routinely prepared for rainfed agriculture. However, it is essential to incorporate water resources as a critical input and develop land use plans that consider optimum utilization of water resources at different planning scales. The edaphic approach is too sectoral and lacks multidisciplinarity. The following table shows research gaps, resultant effects and implications for the future research work and policy decisions.

Existing research gap/constraint/problem	Effect/Consequences /Implications	Remedial Suggestions
Data required for land use planning are not available or available at multi scales	Inconsistent land use plans. Decision makers are not confident resulting in sub optimal utilization of resources.	A protocol for data collection to be developed and followed for national, regional and micro level land use planning. Georeferencing of all the data to be made mandatory.
Land use conflicts and concern about losing fertile lands to non agriculture uses.	Significant loss of agricultural production.	Most suitable lands for high agriculture production to be delineated to facilitate decisions after appropriate evaluation of potential loss.
Landless population is neglected in all the land use plans/studies because LUP is viewed as a process of using land especially agricultural land. The latest National Sample Survey Organization study (1999) on the role of land, water and forest commons in the life and economy of rural Indians has revealed that CPRs provide as much as 58 % of fuel wood requirements and up to 25% of fodder requirements. It also provides evidence of large-scale depletion of CPRs, with CPR lands in rural India declining by almost 2 % every five years (Goswami 2011).	Major part of the population is left out of the development process. A large majority of over 75 billion rural population of India are dependent on CPRs for their livelihood (Pradhan and Patra 2011) and yet the issue of land use planning in CPRs has remained neglected mainly due to the protected nature of these resources, where no change of land use is possible (as in case of forest), or the possibility of no modifications in its characteristic (as in case of village ponds, common grazing land)	Encourage policy that aims at protection and optimal utilization of common property resources such as pasture lands, water bodies, community forests *etc*. Develop LUPs encompassing growth of non timber forest produce species on common lands.

Socio-economic factors are ignored with disproportionately higher emphasis on soil resources, their quality and ability to support an agricultural crop.	Low acceptability of land use plans by administrators, decision makers, planners *etc*.	Shift to integrated land use policy formulations based on land information, socio-economics and environment concerns.
Available water resources in the planning unit are not taken into account. LUP is confined to rainfed agriculture. Implicit to such planning is an assumption that irrigated agriculturists need not be offered or do not need any land use planning advice and crop choice is entirely decided by amount of water available.	The perspective of raising less water consuming crops for food security is not addressed. Similarly “What if” simulations to facilitate policy decisions such as offering incentives to farmers cultivating less water-intensive crops are lacking.	All future studies, policy analysis to include water resources data as an integral part.
Wide difference between expert opinion and field reality/farmer’s opinion about crop choice. For instance most of the land in Yavatmal district of Maharashtra is termed unsuitable to cultivate cotton and yet the existing cotton cropped area exceeds 60 %.	The low input, drought resistant cereals like sorghum and millets were fast replaced by cotton and soybean during the last decade. The district is also infamous for cotton farmers’ suicides. There was a spread of intra-hirsutum hybrids from 40-45% of the cotton area in 2002 to 92% in 2012, a concomitant decline in the area under *desi* (*G. 0rboretum* and *G. herbaceum*) and Egyptian (*G. barbadense*) cotton from 31% to 3% during the corresponding period (Venugopalan *et al.* 2015). Its immediate fall out have been a skewed market surplus of long staple cotton and a huge shortage of both short staple cotton needed for non spinning application and extra long staple cotton needed for premium textiles.	Weaning away the farmers from cotton cultivation especially in land parcels unsuitable for growing cotton crop is a major challenge. It calls for defining area to be covered under each type of cotton annually with targeted production and allocating suitable lands for this purpose. Major cotton producing federal states need to prepare a joint policy to keep the area under cotton crop optimal. A paradigm shift in approach would be required as input costs differ across regions. Development of Decision Support System that simulates different scenarios at national scale would be the first step in formulating land use policy for cotton.
Similar wide difference between expert opinion and field reality/farmer’s opinion about crop choice.	A mismatch between suggested land use/crop choice and farmers’ choice.	By extension above (cotton related) exercise could also be useful for major cereal crops, pulse crops of the country.

Acceptability of Land Use Plans.	Because of several factors the land use plans prepared by experts do not find acceptability amongst the planners, policy makers and stakeholders. Existing institutional mechanism does not support or provide legislative backing to the land use plans and hence LUP is by and large academic exercise with limited and sporadic execution.	National priorities for land use and crop choice need to be defined and mechanism to be set up to implement decisions taken in national interest. The local land use plans must be in sync with national land use plans. Guidelines may be issued for preparing for formulation of land use plans that consider national objectives such as food security, livelihood to landless population *etc*.
The plans do not indicate economic value of existing and proposed land use or comparison with neighboring unit. For *e.g.* existing productivity of cotton in nearby village/district to gauge potential of introducing the crop, or national production so that decision maker can decide if the crop is already in excess or information on market/infrastructure.	Non acceptability of LUP by stakeholders.	Economic evaluation to be made an integral part of Land Use Planning.
Provisions for supporting livestock is not made in LUP	Decision maker, administrators are not able to take informed decisions.	Information on livestock to be analysed for better land use plans
Land use plans do not address Bio-diversity or environment protection and ecological services issues.	No information on potential loss or implications resulting in ill informed decisions	Integration of eco-services as an integral part of LUP and economic evaluation of such services to be inducted in all simulations/analyses. Eco-sensitive zones to be delineated and evaluated for the ecological services they provide.
Negligible research interest in LUP outside NBSS and LUP due to lack of skills and access to required data	Lack of well defined land use policy	Raising awareness levels, Human resources development for LUP research. Geo-portal will overcome the inadequacies partially by providing soil data. Other data also need to be made accessible
Lack of linkages with other natural resources organizations	To link the land use priorities of prime agricultural lands with non- agricultural land use	It will help to develop integrated land use plan for diversified land use types

Conclusion

Research work in the field of land use planning was reviewed and important milestones such as development of Agro-Ecological Region map of the country, development of soil suitability criteria for different crops grown in the country, customised soil survey for a commodity of interest like rubber, land use plans implemented at watershed and village levels and suggested land use plans for different administrative units were discussed. The constraints in developing land use plans like scale, need to refine soil suitability criteria, hitherto unaddressed issues like including common property resources, water resources, pasture lands, village commons, NTFP *etc*. were highlighted. Future areas of work like land resource inventory of the Nation at 1:10000 scale and LUP priorities like mapping prime lands for agriculture, studying land use changes and their impact on water availability, refining soil suitability criteria, delineating management units for nutrient management *etc*. were spelt out. It is recommended to georeference all data related to LUP, a protocol to be developed to bring consistency in data collection, include water resources, livestock data in preparing LUP. We also emphasize economic evaluation of land to be made integral part of LUP. It is essential to establish strong linkages/network of all agencies engaged in natural resources management and rural development. Forest, livestock, water resources development, environment agencies and space organization need to work in close collaboration with agriculture department for better future.

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