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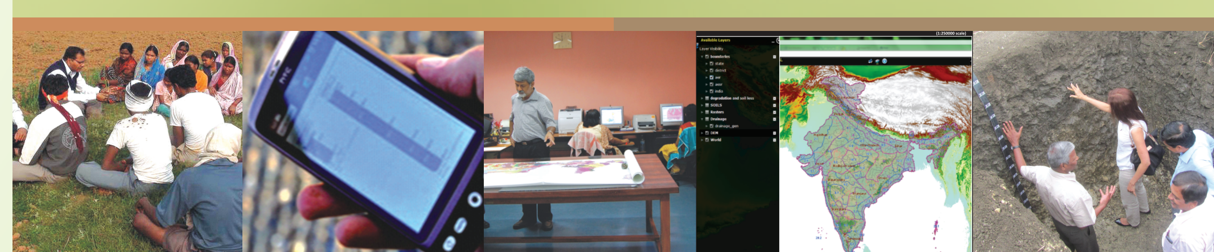

National Bureau of Soil Survey and Land Use Planning

Indian Council of Agricultural Research

भाकृअनुप
ICAR

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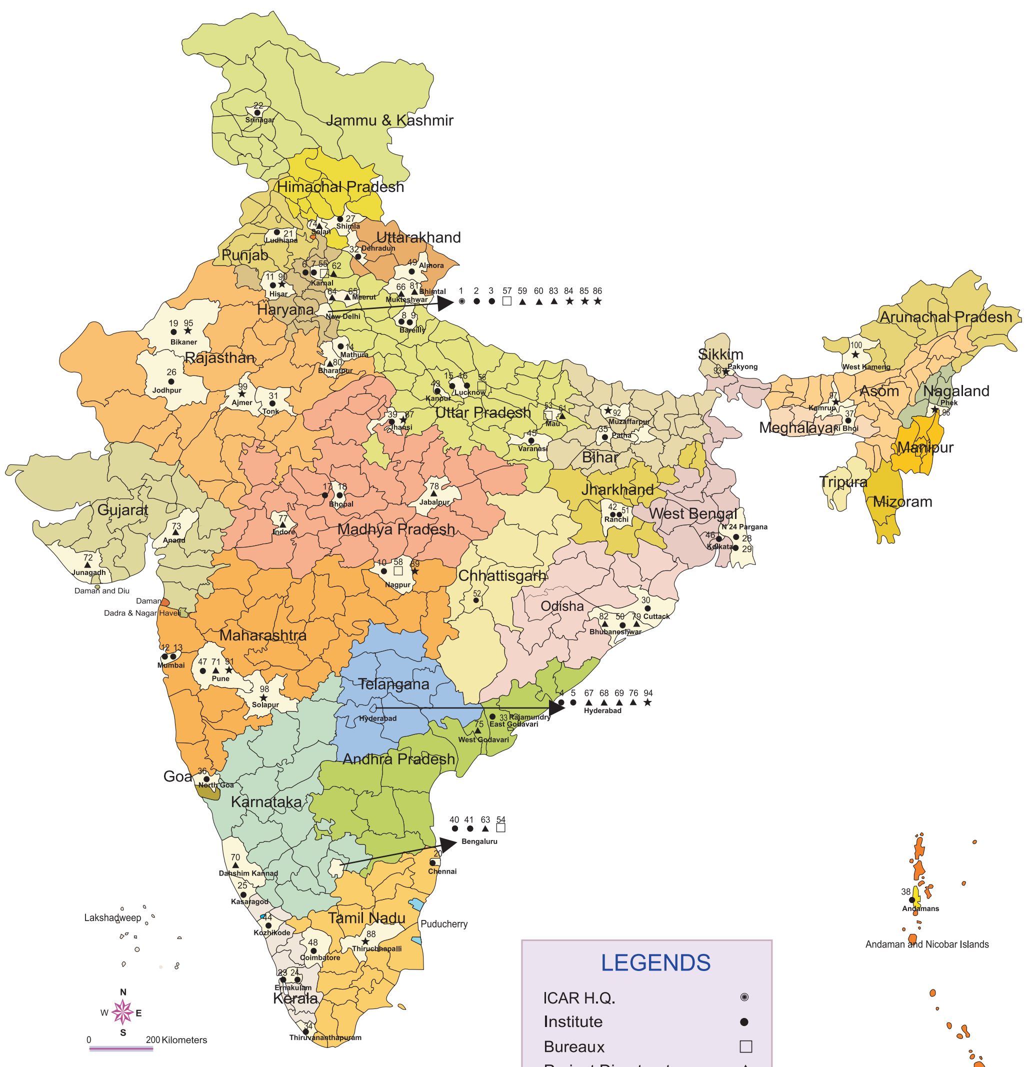

LEGENDS

- ICAR H.Q.
- Institute
- Bureaux
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Vision
2050

National Bureau of Soil Survey and
Land Use Planning
(Indian Council of Agricultural Research)
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संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)
केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

(S. AYYAPPAN)
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Preface

It is being increasingly realised that soil and land resources of the country are to confront serious challenges in 2050. Shrinking land resources as a result of country's galloping population continued degradation in the years to come. Changing climate and its impact on soils and land use, misuse of prime agricultural land for non-agricultural purposes and non-judicious planning of land use will be the key challenges to overcome. Alongside, there will be of course, opportunities, emerging in the form of new science, tools and techniques. All these would necessitate a change in paradigm in formulating and implementing the soil survey and land use planning research programmes in the country. This, in turn, would need National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) to develop perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science.

I am extremely pleased to present the Vision 2050 document of the NBSS&LUP that reflects the collective understanding, aspirations and determination of its staff to realizing the vision. The document highlights the issues and strategies relevant for more than three decades.

I thank Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR, New Delhi for laying down a road map of Indian Agriculture vide Vision 2050 through his visionary wisdom and also for inspiring the NBSS&LUP to undertake this important task. I take this opportunity to also thank Dr. A.K. Sikka, Deputy Director General (NRM), ICAR, Dr. B. Mohan Kumar, Assistant Director General (Agro & AF), ICAR and Dr. S.K. Chaudhari, Assistant Director General (S&WM) for providing much needed support, guidance and encouragement in preparing the document.

I also put on record the valuable inputs received from Dr. S.K. Sanyal, former Vice-Chancellor, BCKV and Chairman, Research Advisory Committee, its members and members of the Institute Management Committee towards improvement of the document.

I also thank all the Heads of the Divisions and Regional Centres for providing valuable suggestions from time to time during the preparation of the document. I am happy to put on record the genuine pains taken by the members of the Editorial Committee namely, Dr(s) S.

Chatterji, J.D. Giri, T.K. Sen and N.G. Patil in preparing this extremely important document. The technical support received from PME Cell staff is sincerely acknowledged. The sincere involvement of the stakeholders during its preparation is gratefully acknowledged.

A vision not followed by actions remains a dream, the NBSS&LUP is, therefore, committing to itself, the ICAR and the society its firm resolve in undertaking sincere and dedicated efforts towards realising the vision.

S.K. Singh
Director
ICAR-NBSS&LUP, Nagpur

Contents

Context

When you hold your vision in your conscious mind, you are focused on what's in front of you instead of what's behind you. You are focused on what you can do, and not what you didn't do. Visionaries are excited and passionate as they create the future they most desire.

– Adapted from Debbie Ford, "The Shadow Effect"

The human population of India is estimated to increase to 1.6 billion in 2050 from the current level of 1.2 billion and the food grain production would need to be raised to 581 millon tonnes from the present level of 241 million tonnes (Ghosh, 2013). This additional food requirement will have to be produced from the projected cultivable land of 142 million hectares (Kathpalia and Kapoor, 2011). However, the fact that per capita land holding will go down to an abysmally low 0.087 ha, poses a grave concern (Sharma, 2006). Also the price of land is likely to be almost 10 times higher than the present value in the land market. In such a scenario, the resource poor farmers will no longer be interested in cultivating their lands and would much rather sell their land to corporate houses. Moreover, with the improvement in literacy, the younger generations will prefer to shift to manufacturing and service sector which provides much better employment opportunities and improved standards of living.

The present water availability for the country as a whole is around 2000 BCM which will go down to 1500 BCM by 2050 thus downscaling India from a status of water sufficiency to water scarcity (Amarsinghe et al., 2007). Crop land available for production may be reduced by 20 per cent by 2050 due to land degradation, urban expansion and conversion of crop land to non-food production (Sharma, 2006). Land degradation, in particular, will negate all efforts to increase crop yields.

As much as 121 m ha land is reportedly degraded (ICAR-NAAS, 2010), and at the current rate of decline in productivity of soils due to deterioration in their quality, the scenario for 2050 appears dismal. Degradation of land leading to impaired soil quality is the greatest impediment and will prove dangerous, if neglected. It is imperative to check and reverse land degradation without any further loss of time. The improvement in productivity will have to come from sustainable intensification measures that make the most effective use of land and water resources.

Vulnerability to climate change is another serious issue. It is expected that by 2050, there will be a drop in total precipitation in Indian sub continent by 20% and an increase in mean annual temperature by 1 to 3° C (IPCC, 2007). With an economy closely tied to its natural resource base and climate sensitive sectors such as agriculture, India may face a major threat because of the projected change in climate. Land resources, their distribution and quality, and land use in India will be hit hardest by climate change (NAPCC, 2009). This could bring in bigger declines in crop yields and production. These have serious consequences for both, the kharif and rabi crops. Because food (crop) production is critically dependent on local temperatures and precipitation, for crops have thresholds beyond which growth and yield are compromised (Ghosh, 2013), any change outside the range of reasonable tolerance would require farmers to adapt their practices accordingly.

The situation, that is likely to arise by 2050, suggests that no amounts of material inputs are going to enhance the productivity of our soils required to meet the demands. We would require new knowledge-based technological innovations to augment the effects of various inputs like water, energy, fertilizers and human resources (Ramesh Chand, 2012).

Another issue affecting the productivity is the rampant encroachment of prime agricultural lands from competing sectors. There will be fierce competition from other users like housing, industrial and health sectors and other economic activities cardinal to the country's development. When prime lands are no longer available, there would be a corresponding pressure to destroy forests and fragile lands in an attempt to convert them to agricultural production. All efforts need to be made to prevent the diversion of lands from agriculture to non-agricultural uses through negotiations and legislations. Before undertaking these efforts, we need to collect information on the extent and distribution of prime agricultural land available in the country, document it and reserve it solely for agriculture. There is, sadly enough, no information available at present on how much of prime agricultural land has been taken away for non-agricultural purposes especially during the last two decades of economic growth. The ICAR-NBSS&LUP (hereinafter to be used interchangeably as Bureau) in a recent study reported that 180 m ha of deep soils are spread in different agro-ecological sub-regions (AESRs) of the country and proposed that they should be conserved for agriculture and policy should be formulated so that these lands cannot be diverted for non-agricultural use (Mandal et al., 2012).

This problem becomes even more severe in a market driven, unplanned diversification as well as urbanization of that land to non-sustainable development. Demand driven or market driven land use changes can severely impact the natural resources of the country which may not be conspicuous immediately, but would cause long term damage. Hence, judicious land use planning becomes imperative. Biophysical characteristics largely determine the land use patterns. Hence, we need soil and land resources information base for each parcel of land. The current status of knowledge is inadequate. It may be worth mentioning here that the Bureau has recently launched a project, 'Land Resource Inventory (discussed later in detail) on 1:10000 scale for agricultural land use planning to generate this information. Mitigation measures to combat climate change also need to be based on soil information. Currently, market forces influence the land use decisions to an extent that the planners are left with restricted space for alternatives. Socio-economic factors such as, economic development and technological change (besides population growth) have been projected to influence land use decisions in 2050 on an even larger scale.

There is no scope for agriculture to retain its present subsistence driven pattern. There has to be a qualitative change from subsistence agriculture to business oriented agriculture backed by market forces. Our government should devise policies to consolidate land and promote group/cooperative/contract farming. Apart from focusing on self-sufficiency, farming should be on the basis of cooperative advantages. With very little scope for any additional land being made available, agriculture has to be knowledge intensive and precision oriented to get substantially higher production without any risk to sustainability. Improved fertilizer use efficiency, water use efficiency, soil quality, etc. will have to be achieved at a much higher scale than at present to keep agriculture an available proposition. Maintaining soil quality through improving soil organic carbon status, soil and water conservation, nutrient retention, preventing salinization, water logging and improving soil aggregation, etc. are absolutely necessary for us to be in a position to meet the demands of the situation arising in 2050.

NBSS&LUP in 2050

Envisioning what the NBSS&LUP will be in 2050 is in itself a very complex task that will need a thorough and rational understanding of its relevance in the Natural Resource Management sub-system of ICAR system and to the society at large.

Mandate

- To conduct soil survey and mapping of the soils of the country to promote scientific land use planning in collaboration with relevant institutions and to coordinate soil survey activities in the country.
- To conduct and promote research in the areas of Pedology, Soil Survey and Mapping, Remote Sensing Applications, Land Evaluation and Land Use Planning in collaboration with other relevant agencies.
- To impart training and education in Pedology, soil survey and land use planning to create awareness on soil and land resources and their state of health.

The NBSS&LUP has now come to the cross roads and now it is time to take stock of its achievements made so far, the major ongoing RD&T activities, the challenges (Chapter 2 – Specific Challenges) that it will face so as to live up to its role of a provider of solutions to the ever increasing threats that the country's natural resources, notably the soils are facing and also to the problem of their un-scientifically planned use.

Major RD&T Achievements

The Soil Survey and Land Use Planning RD & T activities in India have been largely handled by the NBSS&LUP. The NBSS&LUP, through its journey of almost 4 decades, has every reason to feel proud of its tremendous accomplishments in the domains of research, development, and training. There are numerous achievements of which the most important include the publication of Soil Resource Map of the country on 1:1 million scale and its different states (on 1:250,000 scale); development of new concepts in genesis of soils; publication of a 20-Unit Agro-ecological regions and a 60-Unit Agro-ecological sub-region map of the country that proved immensely useful in national and regional level land use planning; cost effective and time efficient use of remote sensing data in mapping of soils at various levels; establishment of 300 benchmark soil series in the National Register, generation of reliable estimates of degraded land in the country, estimation of carbon stock in the Indian soils, farm level land use planning under institute village linkage programme (IVLP) using 'Participatory Rural Appraisal (PRA)' tools; development of land use options for different operational units spread over 5 agro-eco systems, namely Rainfed, Irrigated, Arid, Hill & Mountain and Coastal.

In addition, NBSS&LUP has also generated qualified and skilled manpower in soil survey, micromorphology, geoinformatics applications, land use planning and land resource management through its cutting edge training programmes and Post Graduate teaching and research programme. The Bureau has identified different stakeholders for pursuing its research and development programmes, interfacing its activities with State Agricultural Universities, ICAR institutions, NGOs and other research organizations through a multidisciplinary approach that greatly facilitates a better understanding of soil and land use problems and their redressal.

MAJOR ONGOING ENDEAVOURS IN SOIL/LAND RESOURCE INVENTORY AND LAND USE PLANNING

Land Resource Inventoring for Agricultural Land Use and Development of National Portal on Soils

Lack of site-specific data, particularly on soils, and of situation-specific recommendations, have been the causes of failure for most of the development schemes that operated in the past. This project plans to fill this vital gap by generating site-specific soil and other land resources data. The project would be executed by using modern techniques, tools and facilities in a consortia mode by involving State Departments of Agriculture, State Agricultural Universities, State Remote Sensing Applications/Services Centres, National Remote Sensing Centre, Soil and Land Use Survey of India. The ICAR-NBSS&LUP will act as a nodal agency by providing required scientific/technical back-up. The ICAR-NBSS&LUP in collaboration with National Remote Sensing Organizations will facilitate establishment of the National Portal of Soil and other land resources of the country for effective dissemination of information.

Quantitative Land Evaluation Using Modern Tools

Recent land evaluation research is focusing on the application of quantitative procedures. Availability of spatial soil data bases, advances in crop modeling, fuzzy methodologies and GIS techniques are facilitating this. The Bureau has already calibrated and validated some simulation models (INFOCROP, WOFOST) and fuzzy techniques and is applying them in quantitative Land Evaluation. Risk assessment in adopting a particular land utilization type (LUT) is also being undertaken.

District Land Use Planning

A National network project on the "District level land-use planning and policy issues under different agro-ecosystems of the country" has been taken up by the Bureau. The project aims at developing methodology for generating district level land use plans and delivering a decision support system that will provide uniform land use decisions.

In order to prepare itself for meeting the challenges in 2050, the Bureau has followed a prescriptive approach. It first anticipated the situations that may arise in 2050 from the present trend of deterioration of natural resources, expanding population, conflicting demands, increasing demand for food and fibre for humans and animals, etc. How the Bureau will prioritize its research activities (using relevant technologies), so that it will be in a position to meet the situation in 2050 should form the basis of developing a Vision for 2050. The Bureau's strategy, therefore, should be two pronged (1) Inventorying soil/land resources at village/farm level, classification of this data based on soil characteristics detailed fast-track soil survey of the agricultural land (at village/farm level) of the country would be needed to generate information (database) on land and soil parameters and develop soil quality indices at farm level. This will be in addition to undertaking demand driven soil resource inventory at different scales, and (2) land use planning based on soil/land resource data, and other natural resources, socioeconomic potentials and constraints.

In particular, developing large size land use plans (at farm level) for farmers based on, among others, land capability and suitability principles would be extremely essential. This becomes all the more important for efficient utilization of land resources of each and every parcel of land to ensure higher productivity. Moreover, the average holding size of farmers is expected to come down substantially in 2050. Shrinking farm sizes in India cannot be whisked away and hence prudence lies in being able to innovate and develop land use plans for these small holders. The Bureau has to gear itself up to shoulder the responsibility of delivering such high utility maps and thereby contribute to increasing food production in the country.

There should be a proper assessment of population scenario vis-a-vis land mass available to meet the increased and varying food demands of the country in the scenario of improved lifestyles. At present, there is no land use policy in the country to stop indiscriminate diversion of agricultural land towards non-agricultural use and attendant land degradation. Enactment of legislation with stringent provision for conservation of prime agricultural land for agriculture much before 2050 is a crying need. Land capability classification and land suitability classification should guide land use decisions. Government will have to play a proactive role in land capability/land suitability-based land use decision making process through enacting legislation in the farm of land use policy to ensure sustainable food security for the 1.6 billion Indians in 2050. Besides, based on the projected best and worst climate change scenario, there would be a need to simulate land capabilities that could withstand these changes. Last but not the least, there would also be an essential need of improving capacity building activities and developing infrastructural facilities to meet these projected challenges.

Challenges

General Challenges

- Ensuring food security vis-à-vis demographic pressures, degrading natural resources, dwindling land holding and uncertainties of climate change.
- Conservation of natural resources notably soil and water, development of viable technologies to meet the demands of increased productivity of foodgrains.
- Maintaining soil quality.
- Seeking new directions in agriculture through adaptation of strategies, policies and actions.

Specific Challenges

The NBSS&LUP would, at the first place, be required to generate soil resource databases and maps and land use plans on different scales in response to the specific demand that would emerge as a result of various challenges. It will have to re-orient its research priorities and adopt and further develop modern, cost-effective methods for collecting, analyzing, interpreting, and presenting soil data. The reach of soil survey would need to be extended by not only considering geneforms but also phenoforms of given soil series reflecting the effects of different types of management. Changing paradigm of soil survey – problems like soil pollution, socio-economic constraints and potentials will warrant database building on these issues through soil survey. Another major challenge it would face in 2050 is the need to ensure that these soil and land resources databases and maps find applications and the land use plans are implemented which have hitherto been not at the desired level. One of the major causes for hitherto limited implementation of land use plans has been their over-dependence on soil information. The NBSS&LUP will be required to include other components of land use planning namely, socio-economic (human dimension, in particular), water, animal and land use to make them pragmatic and implementable. Our ability to engage the public in land use decisions will keep the science alive and produce results that are meaningful to society. We have to encourage and ensure greater dialogue between scientists, policymakers and the general public. The hitherto limited ability of the Bureau to translate research results into practical field applications needs to be enhanced in view of the foreseeable and unforeseeable challenges.

Collection and interpretation of national harmonized soil information (soil quality, degraded soils) to provide appropriate soils data to the society in an *Info-centric* world is one of the major pre-requisites for scientific land use planning. Lack of good basic soil data has often resulted in generation of empirical results (e.g. in soil erosion studies) even in the recent past challenging our scientific pretensions. Quality biophysical and socio-economic database need to be developed that can make substantial contribution to limiting environmental degradation. A soil information system is a key to judicious agricultural management. A soil information system needs to be developed and updated periodically for not only monitoring the soil characteristics dynamics but also for taking judicious land use decisions. Moreover, one has to ensure that the information system is developed in a globally retrievable format.

Another major challenge that the NBSS&LUP would face is that of deriving means to manage the dwindling soil resources to meet the requirements of food and fibre of the ever increasing population. Competition for land has reached alarming proportions, resulting in encroachment of prime lands. To arrest this, monitoring of prime land becomes essential and urgent and prime land needs to be mapped and documented at the earliest. Mapping and documentation of degraded, fragile and marginal lands would be another major challenge as this will help in fixing their needs for amelioration, alternate land use, etc. Effective land use planning techniques, tools or models that are easily understood by the vast majority of small and marginal farmers lacking in knowledge and financial resources is the pressing need. Such land use planning models for states, districts, blocks, watersheds, command areas, etc. are very much needed to help planners to decide priority for land use allocation.

Agricultural land use planning on 1:10000 scale would constitute a major activity of the Bureau. It is, however, difficult to enforce land use options on a farm land. The challenge to land use planning is to maximize farm profitability through the land use options suggested. Only then will land use options be adopted. Land use options (generated through land evaluation) are given for a physical dimension, land, whereas profitability is at a household level often not aligned with geographical coordinates. Land evaluation and farming system approach need to be integrated. Economics of alternate land use options would be needed so that more informed decisions can be made.

The coming four decades are likely to see major changes in our land use/ landscapes. Many competing uses such as agriculture, residential requirements, recreation, mining, biodiversity support, forest protection, water provisioning, urban planning, carbon sequestering, and many other land uses will be in conflict with each other. The continued changes will have to be managed in an economically and environmentally sustainable manner. Burgeoning population and changing climate will continue to be a big hindrance in development paths. We need to conceive simulation tools to be able to take guided land use decisions. The priority has to be creation of database and constructing different land use scenarios for assessing the implications of land-use assumptions for the country/state or smallest level of planning-village. Quantification of land use decisions on national economy must be understood and various scenarios be simulated to take steps for better policy decisions.

The policy makers will have to be made aware of the projected impact of soil degradation on productivity in 2050 and the dangers of inappropriate land and soil management. The NBSS&LUP will be required to ensure that government and policy makers develop (and subsequently enforce) policies based on the scientific concepts of land use planning namely, land capability and crop suitability classifications.

Improving the quality of human resources and standards in infrastructural facilities would be another major challenge for the Bureau to enable it generate standard outputs. Besides equipping the scientists with knowledge through national trainings, it will need to provide opportunities to them to experience international standards in their areas of work through trainings abroad. Establishment of state-of-the-art laboratories will be another essential requirement for any organization to do quality research and generate quality research output. The PG level teaching and research system being undertaken by the organization in collaboration with various SAUs will need to be modernized through upgradation of course curriculum in order to strengthen capacity of the students and make them locally and globally competitive. To accomplish all these, creation of sufficient budgetary provisions will be the foremost importance.

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Operating Environment

Agriculture and allied activities contribute significantly to the country's GDP and also employ 52% of the total workforce. Indian economy is thus an agrarian economy. Higher growth in other sectors has impacted the contribution of agriculture sector to the GDP which has declined from 42.8% in 1960 to 14% in 2011-2012. Despite this, food grains have recorded production increase by nearly five-fold, from approximately 50 m tonnes in 1950-51 to 250 m tonnes in 2011-2012. The present population of 1.21 billion is projected to grow to 1.6 billion by 2050. An estimated increase in the per capita income of Indians from the current level of $1219 to $6735 in 2050 (Kathpalia and Kapur, 2011) is expected to bring change in their dietary habits and would trigger entry of new crops. Understandably, the food grain requirement of the burgeoning population would be huge i.e. from a current level of about 250 million tonnes to estimated 581 million tonnes of food grains by 2050. There is hardly any scope for horizontal expansion of the net sown area. The net sown area for 2050 is projected as 142 million ha, which has been the same for last two decades (Kathpalia and Kapur, 2011). Thus, increasing the cropping intensity through more intensive agriculture, putting more area under irrigation is perhaps the option available to meet this challenge.

But that, in turn, would put the natural resources including the soil (and land) resources under stress. Many parts of the country have already witnessed deterioration in quality of their natural resources as a result of intensive agriculture practices. It is here that the NBSS&LUP has to use its skill to identify areas which are non-vulnerable to vulnerable and suggest strategies for sustaining the non-vulnerable areas and for protection of vulnerable areas so that they are not irreversibly degraded. Bringing out alternate land use options which are practical and economically viable and socially acceptable will be in the realm of land use planning.

All these projections and scenarios discussed above and also in Chapter 1 (on Context)would influence the operating environment of the NBSS&LUP and would, in turn, shape its activities. The overall environment in 2050 would also be impacted by different external and internal factors namely, political, economic, socio-cultural, technological, environmental, legal and institutional and the same is discussed below.

- Development and enforcement of land use policies as per the land capability/land suitability-based recommendations of NBSS&LUP.
- Compliance to international pressure on generation of soil database.
- Core programmes of the government such as, food security mission, tribal sub-plan, etc. would drive land use changes.
- Declining trend in per capita availability of land resources as a result of ever increasing population pressure and land degradation.
- Consequences of creation of Special Economic Zones (SEZs) and misuse of prime agricultural land for non-agricultural purposes.
- Conflicting interests of stakeholders in deciding the land use.
- Incapability of the stakeholders to use digital soil resource maps, descriptive legends, interpretations and adopt/implement land use options.
- Survey and mapping of environmentally fragile areas, such as, desert regions,Sundarban delta, Hill and mountainous regions, mining areas, polluted and natural contaminated areas, etc. will shift the institute priorities.
- Copyright issues of data products and legal restrictions on survey and mapping of sensitive areas.
- Development of demand driven soil resource inventory at different levels with special emphasis on village level, basic and strategic research in various aspects of pedology, remote sensing applications and land use planning.

Further, capacity building of the organization staff through training in mandated areas of NBSS&LUP and modernization of the infrastructural facilities to keep in tune with the changing needs will be taken up on priority. In addition, scientists would need to be trained in communication skills to effectively interact with scientists in other disciplines, policy makers, stakeholders and public at large.

Soil survey organizations of the state governments will be rejuvenated to conduct soil/land resource inventory. The Headquarters and regional centres would develop strong linkages with the state governments and SAUs in improving the quality of their soil resource inventory and land use planning outputs. 2050 would also witness a lot of linkages with international organizations for sharing global database, research platforms, etc. Besides, the international institutions would also train our scientists. Similarly, the HQrs. and the Regional Centres will also devise methods to link their RD&T system with stakeholders including farmers through various means of dissemination of information.

Corporate Sector Taking Up Task of Soil Survey and Land Use Planning

It is being forecast that the second green revolution will be spearheaded by the corporate sector. The operating environment in the NBSS&LUP will witness a sea change with the involvement of the corporate sector through farm-firm linkage developed between corporate sector and the NBSS&LUP, even as it as the front end player, goes ahead with expanding its work. The beginning has been made but distant future would invariably witness very many examples of farmers coming together as cooperative or farmer's organization to carry out land use planning with the corporate. The challenge lies in multiplying these ventures across geographies and commodities and ensuring that these models do not fizzle out over time. The future is expected to also witness competition of a much stronger magnitude from various NGOs as they involve themselves in inventorying soil resources and undertaking land use planning.

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Opportunities

Drastic shift anticipated in the agriculture scenario in 2050, as a result of emerging constraints and challenges, would demand a paradigm shift in formulating and implementing RD&T programmes. Newer science and emerging technologies including, among others, remote sensing, space science, IT and nano-technology besides the proven and lasting ones, would offer ample opportunities for meeting the challenges. These will need to be integrated into the existing programmes for effecting the overall change that would be required to meet various challenges.

The NBSS&LUP, through the scientific knowledge and expertise gained over years, would strive to develop research programmes using new science that would be evolving along with the tools, methods, techniques and approaches that would be emerging in 2050 in addition to using the appropriate conventional ones. This will help in developing cutting edge technologies for resource mapping at different levels, characterization of the extrapolation domains of the agricultural technologies, resource information management in GIS framework and applications of remote sensing technology in monitoring land use/ land cover changes and degradation of resource base, in data processing and analysis relevant to soil resource inventory and characterization, land evaluation and land use planning.

Geo-informatics Applications in Soil Resource Inventory and Land Use Planning

The technology of remote sensing, GIS and GPS is continuously evolving with improvement in satellite data resolution and increased availability of multi temporal data and will be able to address emerging challenges in developing resource inventory and monitoring land use planning. The assessment (and mapping) of soil moisture availability in time and space plays a pivotal role in crop planning. The potential of remotely sensed microwave data needs to be tapped for the same.

Precision Farming

With the decreasing per capita land holding and increasing demand for food, getting the most out of the available land will be imperative. The role of Precision Farming assumes great significance in such situations. It will help in drawing optimum benefits from each parcel of land as it will cater to the requirements of the production system to get the desired benefits. GIS and hyperspectral data (both ground and satellite sensors), would hold immense potential in spatio-temporal analysis of soil, land use and cropping systems and assessment of prime agriculture areas that may help in facilitating optimum utilization of soil. Sensor-based soil profile information generators would offer excellent opportunities in reducing time in soil surveys. GIS-aided models would help in integrating the bio-physical and socio-economic parameters in generating site-specific land use plans. Interfacing of GIS and GPS technologies in conjunction with the farm level soil resource mapping would be useful tools in precision farming.

Pedometrics in Soil Survey and Land Evaluation

Pedometric techniques (applications of mathematical and statistical methods for the study of genesis and distribution of soils and quantitative land evaluation) namely, fuzzy logic, geostatistics (like ordinary kriging), hybrid techniques, cokriging and universal kriging would offer excellent opportunities for speedy and accurate soil surveys, mapping and land evaluations in future (NBSS&LUP, 2011). Digital soil mapping (DSM) is emerging as a very potential geospatial tool for accurate soil mapping. The increasing availability of high resolution real time satellite data in combination with the digital elevation models derived topographical attributes has given a solid platform to build up the soil and land resource database accurately which was hitherto very difficult using the traditional soil survey approach.

Software Development and Applications

Keeping the anticipated generation of huge database in next 3-4 decades and the emerging problems, various softwares would have to be developed for their use in soil resource inventory, and decision support system for facilitation of agro-technology transfer, monitoring soil quality and land use planning.

Over the past two decades, the NBSS&LUP has been at the forefront of the development and applications of computer-based systems to analyse data and generate information to support decision on various land and soil related issues. Integrating the expert system tools to provide advice on deciding on soil and land use and management options based on available information and knowledge will be a major concern of the NBSS&LUP. The NBSS&LUP would need to establish an 'IT Cell' for developing and updating Decision Support System for land use planning particularly at large scale (Block/taluka/farm level).

Nanotechnology Applications

Nanominerals, such as, clays offer a controlling mechanism in management of soils and environment clean-up. Characterization of nano-clay minerals is essential to provide database for the frontier of research in natural resource management. Moreover, the energy involved being less in the output of nano-science research, it would be very much environment friendly. The applications of nono-technology will help in improving fertilizer/water use efficiency and exploiting the benefits of precision agriculture.

Soil Quality Assessment and Monitoring

The situation arising in 2050 warrants that soil quality is enhanced and sustained in view of the alarming problems of land degradation, and shrinking land resources. Identification and quantification of physical, chemical and biological soil quality indicators and their monitoring would hold a key to sustain soil productivity.Research in soil microbiology would be immensely useful and contemporarily relevant in 2050. The power of microbes will need to be tapped for mitigating land degradation and enhancing soil quality. Applications of micro-biological processes into technologies will revolutionise soil quality research in supporting sustainable agriculture and ecological harmony.

Soil Carbon Dynamics and its Sequestration

Identification of C-sequestration potential of various current and alternative land use systems (in different bioclimatic regimes) using various C-models constitutes the key component of future research in soil carbon dynamics and its sequestration that would help in minimizing the consequences of global warning.

Land Use Planning – Newer Concepts, Tools and Techniques

There will be need of implementing a land use and development framework that would offer opportunities to preserve and protect natural resources, encourage and support energy efficient land use forms, support land uses (e.g. low carbon land uses) that cut greenhouse gas emissions and facilitate adaptation to minimize the harmful effects of climate change. Solutions to various challenges would also be offered in the form of opportunities through a number of scientific approaches namely, land use intensification in space and time (in space through multitier cropping and in time through double cropping, multiple cropping and relay cropping).

The concept of multifunctional land use planning is expected to hold value in 2050 and beyond as it will not only fulfil the primary function of producing food and fiber but will also assist in providing environmental benefits, such as, land conservation, suitable management of resources/inputs, environmental protection and other advantages like formation of social capital. Land use planning for sustainable transition of the country to a Low Carbon Society (LCS) social, economic and technological transitions through which societies respond to climate change (Shukla, 2009). The LCS concept offers a window of opportunities for the country in guiding land resource managers to decide about the future flow of energy through choice of appropriate and suitable land use.

The year 2050 will find increased applications of contemporarily relevant anticipatory and participatory tools and machine learning techniques in land use planning. Anticipatory tools, such as, scenario building, crop simulation modelling and GIS-crop model interfacing would be helpful in anticipating and exchanging perspectives about the future of land use planning. Participatory land use planning approach involving use of participatory rural appraisal (PRA) tools would prove very useful for farm level land use planning that would constitute one of the most important activities of the NBSS&LUP. As the volume of recorded data would be growing at an astonishing rate in next 3-4 decades, and the concept of "data mining" will need to be used to describe efforts to analyze datasets automatically for significant structural regularities. 'Machine learning' techniques hold immense potential in supporting decision making in precision farming.

Infrastructural Development

Development of the state-of-the-art infrastructural facilities with sophisticated gadgets and instruments and modernization of existing ones would be an essential need in 2050 to be technologically competent to handle challenges. Modernisation of Remote Sensing and GIS laboratories will be needed with creation of facilities of real time data products, NMR and MIR. Nono-technology has been identified as a very fast growing technology that would find multitude applications in pedological investigations in future. Establishment of a nono-technology laboratory will equip the NBSS&LUP scientists to make rich use of this technology in their research pursuits. Micromorphology would continue to be important research area and, therefore, upgradation of the existing micromorphology laboratory with new sophisticated instruments would be required.

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Goals and Targets

There will be sea changes in next 3-4 decades in resource base, its quality and productivity in response to its overexploitation as a result of increasing population, resulting food demand and climatic variations. As mentioned earlier, the NBSS&LUP is committed to focus largely on its mandated activities of soil resource mapping and developing land use plans across the country (at different levels and for varied situations respectively). The NBSS&LUP aims at attaining the following goals during the next 35-40 years.

- Develop demand driven soil and land resources inventory at different levels with special emphasis on 1:10000 scale inventory.
- Emerge as global leaders in basic and strategic research in pedology, remote sensing applications in soil resource mapping and land use planning.
- Generate contemporary land use plans on 1:10000 scale.
- Adapt RD&Tprogrammes to address contemporary societal challenges.
- Emerge as a Centre of Excellence through capacity building (HRD) in soil survey and land use planning.
- Suggest perspective land use policies for varied situations.

Goals	Target	Expected achievements/ outputs	Measurable outcome/ impact
• Develop demand driven soil and land resources inventory on 1:10000 scale	• Develop soil and land resource database and maps on 1:10000 scale	• Digital database on nature, distribution and extent of soils on 1:10000 scale	• Judicious land resource management
	• Establish benchmark soil series in the National Register for transfer of technology • Develop 'Benchmark soil series Bank'	• Enrich 'National Register' with new Benchmark soil series database and maps.	• Soil-based agro-technology transfer system
	• Develop soil degradation map on 1:10000 scale evolve suitable soil and water conservation techniques/practices	• Digital database and maps on nature, extent and distribution of degraded soils	• Site-specific conservation and reclamation measures for degraded soils

Goals	Target	Expected achievements/ outputs	Measurable outcome/ impact
• Emerge as global leaders in basic and strategic research in soil resources	• Develop concepts and knowledge base on soil formation under changing scenario of climate, land use and management	• New concepts developed on soil genesis	• Knowledge base on the impact of present of climate and management on soil genesis
	• Development of Indian soil taxonomy rationale • Development of user-friendly classification system	• A more acceptable soil classification system	• Realistic and pragmatic resource planning
	• Explore applicability of remote sensing and GIS techniques and assess their effectiveness and efficiency in soil resource mapping	• Relationships between sensor signals and soil properties • GIS-aided soil resource maps using these relationships	• Time efficient and cost effective precision geo-informatics techniques
	• Agro-ecological regionalization	• Novel criteria for agro-ecological mapping at different levels	• Revised agro-ecological maps at different levels
	• Understand relevance and importance of soil functions in eco-system services and generate soil quality indicators and quantify soil quality in different regions	• Soil/land quality database, maps, indicators, and their threshold values • Decision Support System (blue prints) for soil/land quality assessment	• Scientific soil quality monitoring system for sustainable production
	• Develop National geo-portal on land resources	• National geo-portal on soil and site characteristics	• Platform for exchange of soil resource data with national and international agencies, monitoring of soil quality and conducting land use planning
	• Develop soil carbon and other nutrients maps	• Soil carbon and other nutrients reserve inventory and dynamics	• Scientific carbon trading and strategies to mitigate climate change and judicious fertility management
	• Develop indicators of climate change impact (on soils and land use) and soil processes-based mitigation techniques	• Mitigating land degradation and enhancing soil quality	• Improved functional capacity for agricultural soils and degraded lands
• Generate contemporary land use plans	• Delineate crop production zones and evaluate land for land use allocation based on land capability and land suitability classification	• Blue prints for land use allocations	• Informed land use decisions

Goals	Target	Expected achievements/ outputs	Measurable outcome/ impact
	• Optimum utilization of vacant (fallow) lands based on their capability and soil suitability		
	• Develop land use options and management zones (protected areas, regulating areas, reserved areas and guided development areas) on 1:10000 scale	• Dynamic decision support system (blue prints) for land use planning at different levels	• Informed land use decisions
	• Develop Decision Support System for sustainable land resource management	• Decision support system (blue prints) for land resource management	• Judicious and effective land resource management
• Emerge as a Centre of Excellence for capacity building in soil survey, remote sensing and GIS applications in soil resource mapping, land evaluation and land use planning	• Capacity building	• Enhanced/upgraded institutional capacity for staff (NBSS&LUP) and stakeholders	• Skilled land resource managers
• Adapt RD&Tprogrammes to address contemporary societal challenges	• To establish linkage with national and international organizations, stakeholders including farmers	• Linkage networks developed for dissemination of knowledge and information	• Improved and accelerated dissemination of knowledge and information
• Suggest perspective land use policies for varied situations	• To equip the policy makers with policy guidelines on various issues	• Guidelines for land use related planning for legal issues, conducting mitigation and adaptation technologies and regulating the unscientific conversion of prime agricultural land	• Rational land use systems

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Way Forward

In taking action subsequent to developing VISION 2050 document, the NBSS&LUP is required to strive to bring a rational change in its work programmes through the use of the conventional and emerging concepts, tools and techniques towards attaining its goals. It has to also bridge the gaps identified so far in its various research programmes. The analytical approach and forward looking concepts presented in VISION 2050 document will prove useful for the researchers, policy makers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security.The organization will be required to balance futuristic research and problem solving research and the same, in turn, would require it to envision development of cutting edge technologies for characterizing exploitation domains of the agricultural technologies, and optimising resource management. Developing soil resource inventory is the mandate of foremost importance. However, keeping in view the emerging scenario, it will have to be re-oriented and be largely demand driven. Scientific inventory of the natural resources and, in particular, of soil resources, their management and utilization suited to their production potential, allocation of land use for various sectors such as agriculture, forestry, horticulture, agroforestry, permanent pasture, etc. will have to take into account the demands for the basic food, fuel, fibre and timber requirements of the growing population and for promoting export of agricultural commodities and enhancing its share in the national economy.

Development of cost effective, time efficient geo-informatics tools and techniques for inventorying soil resources, assessment and monitoring of soils (including soil moisture) and crop conditions for facilitating site-specific decisions for soil and crop management will be yet another important strategy.

Research efforts will also focus on soil quality assessment and its monitoring through development of environmental indicators (precisely, indicators of climate change impact on soils) like, soil carbon, soil microbial diversity, mineral makeup development of contingency crop plans and formulation of regional mitigation strategies to address adversaries of the changing climate.In implementing any land use strategy, the issues of limited soil resources and sustainability of their productivity will have to be given due importance. Since the pressure on the available soil resource shall continue to increase with time, effective and rational use of this precious resource will apparently be an important strategy to increase productivity on a sustainable basis to achieve targeted goals of foodgrain production. A critical appraisal of the existing scenario implies that the future success to attain the sustainability goals will depend upon the appropriate and efficient use of the land resources.

The policy makers will need to be provided with the best possible estimates of greenhouse gas emissions and carbon sequestration, scaled up with soil survey maps and data. Standards and protocols of Land Use Policy will have to be developed for conflict mitigation and support land use systems that would target increasing the agricultural produce, while conserving soils, using water efficiently, providing livelihood needs and simultaneously serving family consumption. All the available land will have to be used, but use specificity will need to be spelt out like which land will be earmarked for crop cultivation dumping nuclear waste or electronic garbage, etc.

Stakeholders (including very much the farmers) will be essentially involved in the very process of land use planning and their varied interests that result in conflicts will have to be taken into consideration. Methods would be evolved to link research and development system with stakeholders including farmers for accelerated adoption through information and communication technology and transfer of digital data. National Land Resource Information System will be developed and constantly updated to facilitate dissemination and decision making. Research and development system will need to be linkedwith society by improving science communication. Awareness and sensitization programmes would be developed on importance of soil and its sustainability for addressing the issue of food security.

Capacity building of its staff through national and international trainings, organisation of training for its stakeholders, establishment of International Training Centre to train scientists from various developing and underdeveloped countries and help them overcome technology orphanage, and development of state-of-the-art infrastructural facilities in keeping with the changing needs, recruitment of scientific personnel from across various disciplines (keeping in mind the projected need of multidisciplinary team for carrying out land use planning activities) would be the key future activities required for meeting the emerging challenges. Last but not the least, matching budgetary support would be one of the most important prerequisites to facilitate implementation of all the RD&T activities.

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