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JUDICIOUS MANAGEMENT OF LAND, WATER AND CLIMATE RESOURCES FOR SUSTAINABLE AGRICULTURE*

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I am very happy to participate in the seventh annual conference of the Association of Punjab Geographers and share some of my thoughts with the distinguished audience present here. I am beholden to the President and members of the Association for inviting me to the conference and providing me this opportunity. The focal theme of this conference ***"Sustainability of Land Resources"*** is very appropriate particularly, taking into account the states like Punjab and Haryana known for ushering Green Revolution in India.

Agriculture holds an important position in the Indian economy; agriculture and allied activities contribute one quarter of India's GDP and employ 58 per cent of the total workforce. Production of food grains increased nearly four times, from roughly 50 million tons in 1950-51 to 213 million tons in 2001-2002. With more intensive agriculture, there has been a rising stress on natural resources in parts of the country. The major environmental problems of intensive agriculture include degradation of soils from overuse of chemical fertilizers, use of pesticides causing health hazards, decline in crop diversity, over-exploitation and deterioration of groundwater quality, water logging and soil salinity. The other concerns include: decreasing land- man ratio and conversion of agricultural lands for non-agricultural use.

Projections are that India will need to produce 375 million tons of food grains by 2025 and 581 million tons by 2050 to achieve marginal self-sufficiency (Table 1). There is no scope to expand the net sown area. Maintenance of self-sufficiency would require increasing the cropping intensity and putting more area under irrigation. Yields under irrigated conditions are generally double or triple the yields obtained under rain-fed conditions. The gross area under irrigation would nearly double from the existing 79 million hectares requiring 994 billion cubic meters of water by 2050, which may be unsustainable.

By increasing the cropping intensity to 157 per cent by 2050, the gross cropped area will have to increase to 223 million hectares by 2050 from the existing 193 million hectares, which may not be easy considering increasing land requirements by other sectors including rapid urbanization. India's ultimate irrigation potential is assessed at 140 million hectares, of which 75.9 million hectares is by surface water and 64.1 million hectares is by groundwater. Based on these estimates, it is projected that 48 per cent of the gross cropped area, i.e. nearly 104 million hectares, will be under irrigation by 2025, which will increase to 60 per cent, i.e. nearly 134 million hectares, by 2050. It means that the gross area under irrigation will nearly

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Table1
India: Projection for agriculture sector

Parameter	2001-2002	2025	2050
Food grain production (million tons)	213	375	581
Net sown area (million hectares)	142	142	142
Cropping intensity (per cent)	136	146	157
Gross cropped area (million hectares)	193	209	223
Gross irrigated area (million hectares)	79	104	134
Water for irrigation (billion cubic meters)	606	780	994
Fertilizer (million tons)	17	37	53

double from the existing 79 million hectares. This translates to 780 billion cubic meters of water requirement for irrigation by 2025 and 994 billion cubic meters by 2050. Irrigation will continue to be the predominant end-use. Its share is, however, projected to reduce marginally from 95.1 per cent in 2001-2002 to 94.5 per cent in 2025 and 93.8 per cent in 2050. Strategies involving technological advances, land use planning, land reclamation, efficient nutrient management, conjunctive use of surface and groundwater, encouraging sprinkler and drip irrigation system, watershed management, drainage of waterlogged saline soils, utilizing treated waste waters, increased use of bio-fertilizers and policy reforms in subsidiary and pricing of water, fertilizers and power, will be required for meeting significantly higher food grain requirements.

With the burgeoning population and increasing demand for good quality land and water for urbanization, agriculture will be pushed more and more to marginal lands and fragile environment. About 107 million hectares out of 329 million hectares total geographical area of the country is degraded due to physical, chemical and biological degradation processes. As per the future projection made on an all India basis, an area of about 13 million hectares is likely to be affected by the problems of water logging and soil salinity in the irrigation commands of India (Table 2). This does not take into account the area under non-commands (lift irrigation schemes), coastal salinity and salinity in ground water irrigated land with deep water table. Water logging, soil salinity and saline groundwater conditions at shallow depth in Haryana are resulting in a potential annual loss of about 37 million US$ at 1998- 1999 prices. Similarly it is reported that water logging and soil salinity has increased at an average rate of 3000 hectares per year over the last sixteen years in the Tungabhadra command resulting in an economic loss of Rs. 250-300 million per year in crop production alone. About 42 per cent increase in area under water logging and soil salinity in southwest Punjab has occurred over a 4-year period (1997-2001). The website of the 'Friends of River Narmada' highlights the adverse environmental impacts of the Sardar Sarovar Project (SSP) in Gujarat, where about one-half of the planned irrigated area is moderately to severely prone to water logging and soil salinization. It is likely that with increasing use of marginal and poor quality water, affected area in ground water irrigated lands is going to increase steeply by the year 2025.

Land Management

The soil is the most important natural

Table 2
Projected area under water logging and soil salinity in irrigation commands

Year	Area irrigated by canals (million ha)	Area affected by water-logging/ soil salinity in (million ha)		Increase in area (per cent/annum)
		Actual	Projected	
Haryana				
1955	2.4	0.01		
1977	3.2	0.46		0.06
2025	3.2		2.00	1.10
India				
1992	17.29	3.47		
2020	45.00		9.0*	
			2.7**	
			11.7	
2025	50.00		10*	
			3.0*	
			13	

* Assuming 20.0 per cent of the area would be affected at any time
** Assuming the area affected would increase at the rate 0.06 per cent per annum in the existing command (lowest of the two figures is taken into account for calculating the area to take into account the area reclaimed and improvement in the situation as a result of new preventive steps that may be implemented).

resource which has been over-exploited. The soil related issues of current concern are: increased pace of degradation due to physical, chemical and biological stresses; decreasing organic matter and deteriorating quality; heavy metal accumulation and nutrient imbalance; low efficiency of applied nutrients and specific micro-nutrient deficiencies. Recent figures on nutrient mining in India clearly indicate that nutrient additions are unable to cope-up the nutrient removal by crops. Increased ratio of Nitrogen: Phosphate: Potash NPK (at present about 7:3:1) from its balanced composition of 4:2:1 has resulted in nutrient imbalance in general and appearance of deficiency of micro nutrients in particular. These issues need to be addressed by focusing our research and developmental efforts on:

- Inventorization, characterization and monitoring of soil resources by applying modern tools and techniques, especially remote sensing and Geographic Information System (GIS) in different regions of the country.
- Development of sustainable land use plans for each agro-ecological sub-region in the country taking into consideration the biophysical and socio-economic conditions of the target groups at Panchayat / watershed / district level
- Development of Integrated Plant Nutrient Systems models for dominant cropping patterns under different irrigation and rain-fed regions for improving fertilizer use efficiency and soil health.
- Determination of quality of organic carbon pools, capacity for sequestering carbon and quantification of carbon stocks in diverse

soils/agro-eco regions. Mapping of existing carbon stocks needs to be carried out to be eligible for futuristic carbon trading. Refinement of technology for conservation tillage and residue management for achieving synergy between nutrient, water and energy particularly, under rain-fed conditions.

- Inventorization, augmentation and quality assessment of available bio/organic resources like nutrient carriers, bio-pesticides, weedicides, soil amendments having potential for organic/bio-dynamic farming in rain-fed regions.
- Promotion of organic farming through demonstration and training on system of organic farming, bio-fertilizers, vermi - composting, enriched FYM/compost etc.

Soil organic matter (SOM), a store house of nutrients, biological activity and indicator of soil quality is showing declining trends in almost all agro-eco-regions. Application of recommended doses of fertilizers particularly, in cereal based cropping systems (rice-wheat) fail to even maintain the SOM levels of 1970's. Under tropical conditions, it is difficult to build SOM even with green manuring and application of manures. Our strategies to build SOM levels in the soil will largely govern the sustainability of agriculture and food and nutritional security. Many efforts will be required to promote large scale use of organic manures, composts and agriculture wastes to increase SOM levels. Soil test reports show that about 70 per cent of Indian soils are deficient in N, 50 per cent in P and 13 per cent in K. It is also proved that increasing deficiency of P and K and other secondary and micro-nutrients is linked to disproportionate application of the higher doses of N in comparison to P and K. Emerging deficiencies of S, Zn, Fe, Mn, B are becoming serious and threatening the sustainability of agriculture in several regions (Table 3). This kind of unhealthy trends need to be reversed through strategic research, development and policy planning for achieving sustainability of land resources.

The use efficiency of N, P and K hardly exceeds 50 per cent, 16-20 per cent and 80 per cent, respectively. In case of micro-nutrients, it seldom increases 5 per cent. Nearly 4.7, 4.8, 11.5 and 4.0 per cent soils are deficient in Zn, Cu, Fe and Mn, respectively. Similarly, boron and molybdenum deficiencies have been reported from select regions. Low efficiency increases the cost of production and also leads to severe environmental consequences. Organic manures are likely to play a significant role in meeting micronutrient requirements. By raising the nutrient use efficiency by 10 per cent, about 20 million tons additional food grains can be produced at the current level of productivity. One of the serious concerns of nutrient management in the Indo-Gangetic region is the widening N:P:K ratio. The present ratio at the country level is 9:3:1 against the standard ratio of 4:2:1 (N:P:K). Further the disparity in nutrient use in different agro-ecological regions is the principal cause of vast differences in crop yields. The fertilizer use varies for example about 13 kg in Assam to more than 170 kg/ha in Punjab. Serious efforts are required to narrow down NPK ratio through fertilizer policy initiatives and agricultural extension system to sustain land productivity. In many regions oilseeds, pulses, legumes and high yielding cereals have started responding to S application. At present the gap between S removal and addition is about 0.5 million tons which is likely to increase to 2 million tons by 2025. Strategies to address this gap will include application of S containing fertilizer and/or utilization of by-products of fertilizers and sugar industry such as phospho-gypsum and press-mud as sources of S fertilization.

Table 3
Punjab: Changes in the micro-nutrient status in soils

District	Year	No. of samples	Per cent Samples deficient			
			Zn	Cu	Fe	Mn
Ludhiana	1970	1730	56	-	-	2
	1998	200	6	0	2	23
Sangrur	1977	360	71	4	7	0
	1998	100	14	0	18	35
Jalandhar	1977	742	45	6	0	0
	1998	100	14	0	13	39
Ropar	1980	500	52	0	0	0
	1994	126	8	0	6	9

Source : Department of Soils, Punjab Agriculture University, Ludhiana

More than 16 million tons of rice and wheat residues are burnt annually in Punjab, Haryana and western UP adding pollution load of the environment. During burning significant amounts of N, P and K are also burnt and released as gas in the atmosphere. Strategies which will promote retention of residues on the soil surface and their slow decomposition during the crop growing period have the potential to generate nutrients *in-situ* for use by the crop. *In-situ/ex-situ* crop residue management strategies will play a significant role in integrated nutrient management. Resource conservation technologies such as zero tillage furrow irrigated bed planting, laser land leveling, LCC, SPAD and green seeker proved highly effective in enhancing nutrient use efficiency. Crops like pigeonpea, soyabean and cluster bean can be grown without tilling the soil after wheat harvest successfully without or with little dose of nutrients. Promotion of conservation agriculture has the potential to rationalize fertilizer use without yield loss and will add to long term sustainability of land resources.

In the recent past there is increase in the use of bio-fertilizers. The response of crops to bio-fertilizer application varies depending upon the environment and cultural practices in the order: Rhizobium > blue green algae > Azospirillum > Azotobactor > P and S solublizers. Their application in low fertility and low fertilizer use areas need to be promoted. There are more than 100 firms in the country manufacturing bio-fertilizers. The advantage of applying bio-fertilizers is in saving N fertilizer ranging from 20-40 kg/ha. There is still a need to improve the quality and shelf life of bio-fertilizers to promote their wide scale field application. Large quantity of domestic and industrial waste water is produced daily in the country. This water has the potential to irrigate 1.5 million hectares additional area and can supply one million tons of nutrients. Such water after treatment can boost production of peri-urban agriculture very significantly. Environmentally safe technologies are required to be developed to exploit nutrient potential of waste waters without entry of associated harmful metals in water-soil-livestock-human chain. Inclusion of trees particularly leguminous ones in the cropping systems helps in building SOM via moderating temperatures in the tropical climates. Trees also help reclaiming degraded soils and building-up of SOM through addition

Table 4
Changes in soil properties (0-30 cm) under different tree-crop combinations in 5 years

Land use system	Organic carbon (per cent)	Available N (Kg ha-1)
Crop based system	+0.07	+10
Eucalyptus based	+0.12	+21
Acacia based	+0.20	+31
Populus based	+0.17	+25

of leaf litter (Table 4) and recycling of nutrients. Role of multi-purpose leguminous trees in harmonizing crop nutrition requirement in cropping systems/multi-enterprise agriculture systems are not fully realized. There is also a need to re-look the role of perennial green manure crops in promoting organic agriculture and substituting fertilizer needs of crops. Tree based land use systems are bound to increase sustainability of land resources.

Contamination of ground water with nitrates is associated with luxurious use of N fertilizers particularly urea in parts of Punjab and Haryana. Unscientific and excessive use of nutrients particularly N fertilizers is bound to contaminate ground water and environment. There is a need of policy to prepare and distribute for use in agriculture bulky organic sources of nutrients after enriching them with chemical fertilizers and standardizing technologies on reducing their bulk. This is important because in the coming years the urban population will expand (about 45 per cent of the total population by 2025) large quantities of domestic and industrial waste waters will be generated which can be used in agriculture to supplement nutrition of crops. Similarly, a long term sound policy and mechanism need to put in place that promotes rational use of fertilizers and narrowing down of NPK ratios. Most of the P and K fertilizers are imported. There is also a need to make long term contacts with the exporting countries to ensure their timely availability at an affordable price.

Water Management

Sustainability of land and water cannot be achieved in isolation. Water use strategies are likely to have significant impact on sustainability of land resources. Out of the net irrigated area of 56.65 million hectares, 17.3 million hectares (29 per cent) receives water as developed through major and medium projects. Of this, about 3.1 million hectares (18 per cent) area is suffering from irrigation induced salinity. Non-consumptive use fractions of water in the saline environment lose their quality and hence value of such degraded lands is very low. This has serious implications for sustainability of irrigated agriculture. As the cost of water resources development goes high and potential sources of water get tapped, it will become increasingly important to devise strategies for prevention of water logging and salinity that results from inefficient irrigation management. Irrigation efficiencies continue to be very low (40-60 per cent). The performance evaluation of large irrigation commands for current level of water productivity that underpin the scope for improvement need to be researched. Since prevention is better than cure, our best approach should be to improve irrigation efficiencies tackled in order to restrict the occurrence of the problem. Where the problem has already set in, there is need to develop technology suitable for reclamation in various agro-climatic-soil regions. Cost of installing and maintaining drainage systems is high, which is the main constraint in its adoption. Secondly, it has to be tackled at the system level rather than as individual farm efforts. Lack of community approach in installing drainage systems will continue to hinder large-scale adoption by private farmers. Public-private partnership could be used to promote the adoption of the technology. There is a need to develop low cost drainage technology including bio-drainage strategy, to make it acceptable to farmers and do more research on strategies for disposal of saline effluent for on–farm use, by growing more tolerant crops and trees-cum-brackish water fish ponds and for their final disposal for off-farm uses like evaporative ponds, bio-saline agriculture and for salt manufacture.

The projected water demand by 2025 AD for India is 1447 x 109 m3 year-1, out of which nearly 68 per cent will be utilized for irrigation and the rest for other purposes. Due to increasing competition, good quality water will have to be used most judiciously. As the proportion of urban population goes up, the demand for better quality water will increase due to better lifestyles. The present per capita availability of water is 2100 cubic meters and represents a comfortable level. The population expansion will reduce it to 1700 cu m, the accepted scarcity level by 2025. In another five to six years it would slump to the water shortage level of 1000 cu m, currently in existence in most Middle East countries. Water, not land would be the major constraint in producing enough food for the population at that time. The shortage still covers both fresh and recycled waters. So, improved water management will be called for, like provision of more storage and regulation of water during times of water surplus for use in times of water shortages, water conservation by minimizing water losses, increasing food production per unit of water, transferring water to users with higher socio-economic return and reusing saline, sewage and industrial effluents. Short-term solution may in-fact transfer the problem somewhere else in the basin. Therefore, integration of regional level management taking due care of field/farm level management and resources should receive priority. Efficient conjunctive management of water resources at regional level should receive the maximum priority. The situation can be improved through strategies involving river basin as planning unit, community participation in the development and management of water resources, appropriate water pricing policy to encourage resource conservation, rainwater and roof water harvesting, watershed management and inter-basin water transfers can redeem the situation by reducing the water demand by about 25 per cent, from 1060 billion cubic meters to 798 billion cubic meters.

Of the present ground water development of 13.5 million hectare-meter/year, poor quality waters account for 3.2 million hectare meter/year. Agriculture is a major user (83 per cent) of good quality water resources. The current demand of first priority users (domestic use, energy, industry) is around 11 per cent of the total water supply of 62.9 million hectare-meter and will increase to 22.2 per cent (24.3 million hectare-metre) of the total of 109 million hectare meter in 2025 AD. Paradoxical situations of declining and rising water table have developed in the most states of India. With increasing competition for good quality of water from other sectors of economy, agriculture will increasingly depend on marginal quality waters for irrigation. We will also have to cope with greater volumes of effluent, toxic solid wastes, sewage water etc., their effects on soil and underground water quality, and on human and animal health. Problems of water quality will have to be seen in the context of a river basin, where water quality deteriorates towards tail end. The existing temporal and spatial variations in water quantity and quality will get further accentuated and coping strategies, including guidelines and standards for reuse/sequential use will need a fresh look so that land resources are not permanently polluted. Optimum pumping strategies, diversification of crops and recharge technologies need to be developed for areas experiencing declining water tables.

The annual water demand in urban areas is projected to grow at 2.14 per cent to 39.2 billion cubic metres. Overall annual water demand of the domestic sector is projected to grow at 1.54 per cent from the current level of 23.5 billion cubic metres to 50.5 billion cubic metres in 2050. The projected Biological Oxygen Demand (BOD) load from the urban domestic sector assumes an overall waste water collection efficiency of 70 per cent in 2025 and 80 per cent in 2050, from the present level of 60 per cent. Waste water treatment facilities in urban areas are projected to be augmented by 40 per cent by 2025 and by 50 per cent by 2050. The overall annual BOD load from untreated waste water in urban areas is projected to increase from the current level of 3.75 million tons to 7.90 million tons by 2050. Similarly, the BOD load from rural areas is projected to grow from 3.71 million tons to 4.23 million tons estimate for 2025. Key strategies for the efficient management of waste water to avoid degradation of land resources need to focus on augmentation of collection, treatment and safe disposal of waste water; recycling and reuse of municipal waste water; provision of appropriate sanitation facilities; and strengthening of institutional and regulatory mechanisms. These strategies may result in a reduction of 15 per cent in the demand for water, of 57 per cent in the volume of untreated waste water, and the BOD load from untreated waste water will drop drastically by 57 per cent To develop standard guidelines for waste water use will require establishment of referral water and soil quality laboratories.

The water management strategies which need focus are:

1. Future gains in agricultural productivity of the country shall be critically determined by integrated development and utilization of surface and groundwater resources. Of 400 million hectare-metre of annual precipitation, only 29 per cent is harnessed in the country. About 92 million hectare-meter of surplus monsoon run-off is lost to the sea that could be stored in sub-surface aquifers for augmenting the water resources. The indiscriminate use of canal water is leading to water logging and secondary salinization in the major irrigation commands of the country. The increased groundwater extraction has lowered water table at an alarming rate, putting an additional burden on farmers in terms of equipments and energy. In north-west India alone, about one million centrifugal pumps require replacement with submersible ones at a staggering cost of about Rs. 7,000 crores due to the frequent drought situations.

2. It is estimated that even after achieving the full irrigation potential, nearly 50 per cent of the total cultivated area will remain rain-fed and important source of livelihood. Therefore, integrated and holistic development of rain-fed areas within the participatory perspective of watershed management programmes will constitute one of the key elements of agricultural production in future in the country. We need to develop model watersheds in different agro-ecological regions of the country ensuring full participation of local people to demonstrate their usefulness in conserving natural resource and ameliorating the socio-economic conditions of local populace. Conjunctive use of canal and groundwater is called upon so as to save canal water for recharging of ground aquifers. The creation of

a combined canal-tank system of irrigation could have multiple functions such as; fishing, poultry, piggery and other small enterprises. The priority needs to be given to the following issues in the future:

- *In-situ* and *ex-situ* conservation of rain water and its efficient recycling in rain- fed areas to improve productivity and soil quality.
- Multiple use of water for increasing water and soil productivity.
- Conjunctive use of rain water, surface water and ground water for maintaining sustainable hydrologic regime.
- Increasing water use efficiency through efficient utilization of available irrigation water in dry areas through large-scale promotion of micro- irrigation techniques such as drip and sprinklers.
- Ground water recharge and management.
- Use of poor quality waters including industrial effluents and sewage water.

Climate

Climate change and global warming caused by the emission of green house gasses have emerged as an important issue in the last two decades. Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), .hydrofluoro carbons (HFCs), perfluoro carbons (PFCs) and sulpher hexafluouride (SFs) are the six important gases which are responsible for global warming. The recent projections are that South Asia may have an increase in temperature from 0.1 to 0.3 degree centigrade by 2012 and 0.4 to 2.0 degree centigrade by 2070. Sea level rise between 0.15 to 0.94 meter, submergence of islands/coastal areas and change in rainfall pattern over the next century is predicted. This will alter biodiversity pattern and demand a new set of land use pattern. Similarly, stratospheric ozone depletion for winter months has been observed from 1969 to 1988. This kind of ozone depletion may lead to increased ultra- violet (UV) radiation with far reaching adverse impact on earth's environment and human as well as livestock populations. Decreasing trend in density of glaciers may also have serious repercussions.

These weather related issues call for greater understanding of crop-weather relationships and developing crop-weather models to devise efficient agricultural production strategies. The concerns of rising temperature and decreasing ozone protection demands minimizing/moderating the emission of green house gasses. Adaptations to predicted climatic change impacts on productivity include; linking weather forecasting with climate forecasting, land use change, breeding varieties which can adjust to such changes, agronomic manipulations, CO2 sequestration, substitution of fossil fuels with bio-fuels, moderating methane production from agricultural fields and weather based forewarning of incidence of pests and diseases.

Biodiversity

With wide variety of ecological habitants, India supports an enormous diversity of flora and fauna. A significant part of this biodiversity exists in rain-fed regions. Biodiversity is generally distinguished at generic, species and ecosystem diversity levels. For the sake of sustainable survival of mankind, conservation of diversity is of paramount importance. Out of the 18 hot spots of biodiversity in the world, two are in India in the Western Ghats and North Eastern Region. The main areas of genetic diversity in wild types fall under Malabar region, Daccan Peninsula and eastern Himalayas with 113, 96, 51 species, respectively. India has about 8 per cent of the total existing plants and animals of the world. Of 45,000 plant species which exists in India about 15,000 are flowering plant species. There exist nearly 81,000 species of animals in India which is about 6.5 per cent of the total world fauna. Fungi followed by flowering plants constitute the largest group of the total plant components of the Indian biota. A survey conducted in the Himalayan region in the altitudinal range between 1,800 and 3,599 m, showed that the area under traditional species has declined form 85 per cent in 1970 to 55 per cent in 1990. The factors responsible for erosion of biodiversity identified are: mono-cropped agriculture, introduction of traditional crops to non-traditional areas, introduction of irrigation in desert areas, increased pace of land degradation such as erosion, salinity, acidity etc; indiscriminate use of inorganic inputs including pesticides and weedicides and deforestation. Biodiversity conservation should be one of the major concerns of efficient resource management for sustainable production in general and rain-fed regions in particular.

Agro- forestry

A sizeable mass of land in the country particularly, in rain-fed regions faces severe degradation due to deforestation. The present area under forest cover is unable to support demand for tree based products. Fuel-wood is the dominant source of energy in rural areas and small and marginal farmers in rain-fed regions mainly depend upon trees to meet this requirement. These issues call for developing area specific agro-forestry models not only to increase the forest cover but also as diversification and export generating venture. Accordingly, the future strategic planning for agro-forestry should cover:

- Development of area specific agro-forestry models for rehabilitation and reclamation of all kinds of waste and abandoned lands.
- Identification and up gradation of agro-forestry species which can withstand drought, floods and other biotic and abiotic stresses.
- In addition to already existing dominant tree species like Khejri (Prosopis cineraria) in arid areas of Rajasthan, the top feed species such as Ailanthus excelsa, Salvadora oleoides, Prosopis juliflora and edible Opuntia ficus indica have been identified to meet fodder shortage especially during drought situation. Research on such plants should get the highest priority.
- Major thrust in future should be on exploiting agro-forestry as option for carbon sequestration under Kyoto protocol; bio-drainage of waterlogged saline areas; option for environmentally safe disposal of industrial effluents and detoxification of soils loaded with heavy metals and up gradation of productivity of rangelands / grasslands.
- Identification, collection, conservation and improvement of forage crops, grasses and top feed fodder resources and development of agro-techniques for their successful cultivation in rain-fed region of the country.
- Up gradation of productivity, carrying capacity and sustainability of grasslands/ rangelands with major emphasis on alpine and temperate regions.

Crop Diversification

- Continuous cultivation of same crop/cropping sequence in a given area results in fatigue of resources particularly, the soil and water. Recent example is of rice and wheat cultivation for more than three decades in the Indo- Gangetic plain. Higher inputs use to maintain yield levels many times does not help rather results in problems of groundwater contamination and environmental degradation. This calls for diversification to more remunerative cropping systems or resorting to other farm enterprises such as animal husbandry, horticulture, poultry, fish, high value industrial crops etc.

- Medicinal and aromatic crops such as Isabgol, Matricaria, dil, etc. have been identified which can be grown using saline water up to 8 deci. siemens/m. Their exploitation as commercial crops is being explored through linking it with post harvest processing, value addition and agro-based business ventures. More of such industrial high value crops need to be identified and promoted to generate export.
- Identification of biologically more productive, sustainable, profitable and environment friendly crops/cropping systems for different agro-ecological regions of the country in general and as alternate to rice and wheat in particular.

Farming System Approach

It has now been realized that component, commodity and discipline oriented research approach has reached its limits. Any kind of future approach must be holistic involving biophysical and socio-economic settings targeting at inter-disciplinary and inter-institutional synergies. The basic idea should be to exploit growth potential of all the components with rational and efficient use of natural and other resources with particular reference to rain-fed regions. The two issues of paramount importance are:

- Orientation from cropping system research to farming system research focusing on multiple use of inputs and recycling for reduction in cost and resource conservation.
- Integrated farming systems of simultaneous or sequential production of crops, trees, livestock and fisheries after their proper assessment and evaluation is expected to expand livelihood basket. Assessment of farming systems will also be carried out at micro level for their adoption by the farmers with proper testing and monitoring of the suggested farming system. There is also an urgent need of developing a sustainable farming system model for marginal, small, medium and large farm situations in all regions of the country.

In the end, I wish the conference a great success and hope that the deliberation of the conference will lead to some logical conclusions particularly, for the development of land resources.

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