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Proceedings of the Symposium on "Energy Issues in Agriculture"

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1. Energy Issues in Agriculture - presented by Dr. Anwar Alam, SKUAST, Kashmir.
2. Energy Use in Crop Production in India – Dr. Dipankar De, CIAE, Bhopal.
3. Energy Use and Issues in Indian Agriculture – Dr. Nawab Ali, ICAR, New Delhi.
4. Status of Renewable Energy Use in Agriculture and Scope of Future Substitution of Commercial Energy – Dr. B.S. Pathak, SPRERI, Gujarat.

After detailed discussion, the following recommendations were made:

1. Indian agricultural production has witnessed steep rise in commercial energy uses with increase in crop productivity. The dynamic situation would continue in future with rising food demand and globalization of agricultural market.

   The Indian Council of Agricultural Research should launch a national programme with statistical support for periodic assessment of energy use and demand, development of location-specific energy-mixes and identification of energy saving measures with focus on conservation of commercial energy supplementing and substituting with new and renewable sources of energy for effective energy management in the agricultural sector.

2. Preponderance of small and marginal farms, decreasing annual use of farm power sources and equipment requires well developed custom servicing and community facilities for production of agriculture, agro-processing and rural living. Appropriate policy/ strategies need to be framed by the developmental agencies and R&D organizations for strategic implementations and development of appropriate implements as well as farm power machinery management models.

3. Collection, conservation and conversion of surplus biomass for energy application and biofuels can considerably reduce dependence on imported petrochemicals used in agriculture. Therefore, R & D efforts should be intensified in this direction.

4. Animate farm power uses need to be rationalized through development ergonomically desired energy-efficient equipments. Statistical studies should be undertaken to periodically locate the shift of agricultural workers and draught animals from agricultural uses and identify reasons for the same.

5. Researches conducted in the country have located energy saving measures and identification of technologies for renewable energy applications in rural areas. Special efforts need to be made for transfer of such technologies through developmental agencies for early adoption. Statistical studies should be undertaken to generate real time databases on status of technology adoptions and accruable economic benefits for the development of future strategies.

1. Energy Issues in Agriculture

Anwar Alam

Introduction

India has traditionally been an agrarian nation. Farming was done using animate energy sources, organic manures and biopesticides, locally upgraded seeds and planting materials and locally made tools and implements. Productivity levels however, used to be low about

0.50-0.75 t/ha under rainfed conditions and 1.0-1.5 t/ha of food grains under irrigated conditions, sufficient for the population till the 20th century. Independent India took a resolve to prevent chronic food shortage and prevent famine like situation. Intensive integrated efforts led to Green Revolution in 1967-68 and in quick succession to White, Blue and Yellow Revolutions bringing self sufficiency in food grains, milk, fish, vegetable oils, fruits and vegetables increasing production by 3-6 times or even more. Poultry sector likewise made tremendous progress both in eggs and broilers. By 1990s yields started plateauing and second generation problems cropped up-declining factor productivity, excessive post-harvest losses, gains in production and productivity failing to reflect in net returns, reduced margin of profits and so on.

Agriculture in a way is an energy conversion industry through photosynthesis process. Current package of practices of crop production involve direct and indirect uses of energy, some locally available and others commercial resources. Excessive use of energy results in high unit cost of production, loss of profitability and market competitiveness. The ICAR reorganizing the role of energy in agriculture launched 3 All India Coordinated Research Projects. Some very useful results have come out through these projects providing nexus between energy and food, energy efficient crops, crop-rotations and cropping practices and technologies harnessing biomass, biogas, producer gas from biomass, biofuels, solar, wind and animate energies supplementing and substituting costly and scarce petro-chemical fuels and ecologically sensitive fuel wood.

Farm Power for Production Agriculture

Agricultural mechanization in India is directed to have economical and efficient power source that enables the worker to achieve timeliness in field operations for best plant response, precisely meter the inputs and achieve placement that gives best results. It is directed to removing drudgery and imparting dignity to work. Animate unit energy are costlier than mechanical, they need to be fed and maintained when not in work, require work-rest period, equipment available involve excessive walking. Dairy sector has grown primarily through preference to milch cattle and crossbreds, the number of draft animals declining from 81.16 million to 77.69 million during 1977-1992. The annual use of draft animals has also declined from 147 aph/ha to 109 aph/ha. The annual use has declined from 655 hours to 623 hours whereas gross cropped area has increased from 165.8 Mha to 178.5 Mha during the same period.

There has been steady growth in use of electro-mechanical power sources in the country since 1960s and more significantly after the Green Revolution at 10% per annum during 1960-1997. By 2000, tractor population reached to about 2.5 million equivalent to about 0.442 kW/ha from 0.006 kW/ha in 1960. Power tiller manufacture also started about the same time but has not become popular to the extent of tractors, their estimated population is about 125000 and annual production around 15000. Lifting of irrigation water was first to be mechanized in India. Initially stationary diesel/kerosene engine pump set and electrical pump sets were in the ratio of 2:1 but with spread of rural electrification in different states this ratio has reversed. By 2000, pumping sets provided on an average about 0.487 kW/ha of stationary power. The availability of electricity in the villages has improved with 84.8% villages electrified by 1995. Electrical energy generation increased by 8% annually, but consumption in rural areas increased by 8.6%. However, in many states, electricity in rural areas is available for a limited duration and the supply is erratic. Electrical energy is expensive and there are power leakages. Socio-political factors have resulted in tariffs that would not be considered rational. There were about 0.31 million auxiliary engine operated power sprayers and dusters in use. While farm power availability in the country has grown over the years, yet in parts of the country like Eastern India, it is a productivity constraint.

Energy in Production Agriculture

Traditional agriculture was mostly dependent on non-commercial energy sources. In modern agriculture, commercial energy sources contribute bulk of the energy supplies to the production system. The trend of energy use in Indian production agriculture indicates a sharp decline in the contribution of animate energy from 0.55 GJ/t in 1970 to 0.08 GJ/t in 1993 due to continuous decrease in use of draught animals. Enhanced use of diesel and electricity dominated the energy scenario during the period, and consequently direct energy (diesel and electricity) consumption showed highest growth rate of 8.01%. Indirect commercial energy (from fertilizer and agro-chemical) consumption also showed growth of 5.01%. The total energy consumption increased at a growth rate of 4.38% between 1970 and 1993, while food grain productivity during the same period increased by 2.39%. During the period, additional 6.49 GJ of energy has been consumed to increase productivity by one tonne/ha. Broadly speaking, this is a status of energy consumption when only about 30% of cultivable areas of the country have been undergoing a shift to mechanization. The present trend of tractorization and use of irrigation suggests that energy intensity would further increase in the near future. Part time and semi-urban farming besides many others will seek custom servicing in seedbed and sowing, as well as harvesting and threshing.

The energy intensity in Indian production agriculture had been 1.3 times higher than that of total developed countries in 1972 and increased to 1.8 times in 1982. Close similarities in energy intensities are observed between Indian and Near East countries. In general, for obtaining higher productivity, the energy consumption has to increase.

Sugarcane and potato are the most energy-consuming crops while sugarcane-sugarcane and paddy-wheat-maize crop rotations are major energy consuming. Paddy and wheat, the major cereal crops in the country consume about 1/3 energy while groundnut, one of the most energy consuming oilseed crop, require about 0.4 times of energy for their production. Depending upon agricultural practices, the shares of operational energy varies from region to region. Irrigation, using ground water lift irrigation, demand maximum share of operational energy. For paddy cultivation, it ranges between 38 to 91%, wheat 38 to 63%, maize 25 to 77% of operational energy. Tillage, harvesting and threshing operations are generally the next energy intensive operations. Under dry land agriculture, seedbed preparation and intercultural operations are forerunning operations from energy consumption point of view.

For intensive farming, inspite of large population of men and draft animals, supplementation and substitution with commercial energies and their assured supplies are absolutely essential. India not well endowed with liquid fuels is trying to harness crop and energy stock residues through biological and thermo-chemical pathways. Producer gas run irrigation and agro-processing units are coming up. Dual fuel engines run on biogas and producer gas give about 60% of more diesel replacements. Photo voltaic irrigation and lighting systems are in market and new uses of RES are being established. Currently biodiesel is being promoted.

Energy Saving Practices

Uses of appropriate machines with proper application techniques provide ample opportunities for energy saving. Selection of fuel-efficient tractor as per existing workload can save about 10 to 20% of fuel consumption. Proper selection and use of matching equipment can reduce fuel consumption of tractor by 30 to 50%. Underloading of engine, common phenomena in India, induce 20 to 30% wastage of fuel.

About 75% of diesel oil and electricity are used for irrigation. The operational efficiency of irrigation pump sets generally vary between 25 to 60%, BIS certified units operating with 8-15% higher efficiency. Use of flat belt for power transmission reduces system efficiency to 5 to 15%. Specific fuel consumption of stationary diesel engines commonly used range between 200 to 350 g/bhp-h, which is considerably high. Use of plastic pipes with low friction co-efficient save about 55% of energy. Check basin irrigation requires 12 to 40% lower energy as compared to other methods of irrigation. Sprinkler and drip irrigation application systems save about 20 to 40% of irrigation water over flood irrigation method.

Improved equipments have good scope of energy savings. Strip-till drill saves 50 to 70% fuel in field preparation and sowing. Disc harrow-cum-puddler save about 45% of energy in wheat and paddy cultivation. Tractor operated rotavator in light soil saves 20-30% of energy. Zero-till drill and raised bed planters save diesel used in seed-bed preparation and irrigation. Wheel hand hoe save 72% of energy as compared to khurpa. For thresher operation, 7.5-15 hp diesel engine or 5-10 hp electric motor are more efficient than 35 hp tractor. Combine harvesting saves about 40 to 55% energy in paddy harvesting. Digging of crops like groundnut, potato needs much less energy if friable soil.

Conservation of cooking energy in rural homes is an imminent need. Improved cook stoves decrease fuel consumption by 19 to 28% for fixed and portable models, the annual energy saving in a 5 member household averaging 284 and 507 kg, respectively. Use of solar cooker can save 5-19% of energy. Pre-soaking of rice and pulses can reduce cooking time by 5-30 %.

Role of Renewable Energy in Agriculture

Traditionally, Indian agriculture has relied on renewable sources of energy using human and animal energy, organic farmyard manure, composts, green manure, ashes as well as animals herded in the fields, organic products of plant or animal origin. Present day agriculture has, however, shifted to use of commercial energy sources through use of chemical fertilizer and agro-chemicals, growth hormones, oil and electricity. In order to meet the targeted production and productivity, the dependence on commercial energy sources are increasing as in developed countries. Enhanced use of energy has detrimental effect on the environment which can be mitigated by renewable energy. Traditional energy sources constitute nearly 40% of total energy consumed in the country. Decentralized power generation using renewable energy sources; efficient manual and animal operated systems for farm operations; use of solar, wind and biomass for agro-processing operations and rural living are some potential methods of use of renewable energy resources. The Ministry of Non Conventional Energy Sources of the Govt. of India is planning to have renewable energy sources contributing to about 10% of the total electrical power generation in the country by the year 2007.

In the agricultural sector, wind energy have been tried mostly for lifting of water and grinding. The Himalayan Energy Services Company (HESCO) has sponsored WMA (Water Mill Association) in Chamboli representing Gharat-owners in the region. A multi-purpose low-cost cross flow turbine (6 kW capacity) has been introduced in the region that operates a rice huller, oil expeller, and generator. Solar cooker, solar water heater and solar dryer are now commercially available in India. Inspite of high capital investment, solar water lifting systems have been found to be useful in areas where electricity has not reached.

Efforts to use biomass for energy purpose is multi pronged. The annual availability of wet dung is estimated to be about 960 million tonnes. ICAR came up with floating dome biogas plant in 1940, which became popular as KVIC type biogas plant. Later on, Chinese Fixed Dome type biogas plant was adopted and popularized. PAU *Kachcha* Pucca Biogas Plant, as well as GBPUAT, HPKVV and TNAU biogas plants were developed. Studies were also taken up on alternate feed stocks other than cattle dung, measures to increase biogas production during winter months. Currently efforts are underway for biphasic biogas production from biomass that tend to float in water.

India annually produces about 400 Mt of crop residues, which are often underutilized and incinerated for quick disposal. At present, indigenous technology based gasifiers (upto 500 kW capacity) using agricultural by-products are being manufactured. Agro-processing industries are also using biomass as fuel for operating high pressure boilers through adoption of appropriate technologies. Sugar, paper and textile industries are already implementing co-generation of power from organic residues. Technology is available for production of biogas from willow dust, a byproduct of textile industry.

Recommendations

Based on the results available following recommendations can be made.

1. Human and animal energy use in agriculture be rationalized through improved tools, implements and machines that perform efficiently and are ergonomically sound.
2. Renewable sources of energy such as biomass, biogas, biodiesel, solar, wind hydro and geo-thermal be harnessed for agriculture, agro-processing and rural living through intensive R&D efforts.
3. Average farm power availability be enhanced to 2 kW/ha level supplementing animate, new and renewable sources with commercial energy which should be made available at affordable cost, in space, and time.
4. Predominance of small and marginal farmers, increasing part time and peri-urban farming requires that custom servicing in tractors, power tillers, power threshers, and other such equipment to be promoted.
5. Plant nutrients should be realised from agricultural residues and urban refuse to reduce dependence on commercial chemical fertilizers which are energy wise very intensive, costly, and in events of imbalance in use adversely affect productivity.
6. Energy plantation, conversion of biomass needs to be promoted in order to reduce dependence on commercial energies which are getting not only costly but not available when needed most.
7. Cooking is most energy intensive operation in rural living consuming about 80% of total energy used in domestic sector is causing deforestation and damage to environment can be made more efficient through

use of biogas, efficient chulhas, solar cookers, and solar water heaters.

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2. Energy Use in Crop Production in India

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Introduction

The food system of a country consumes significant quantity of energy, the extents depending upon the technology advancements, food habits and purchasing power. In developed economy like of the U.S., production uses 21%; processing 16%, packaging 7%, transport 14% and home refrigeration/ preparation 31%. Generally, processed food requires 10 times of its energy content for making it available on the dining table. Reliable data on energy use in the food chain is not available for many countries, including India.

During the last fifty years, world grain production has tripled (from 631 million tonnes in 1950 to 2,029 million tonnes in 2004). The increasing grain demand has been met primarily by raising land productivity through high-yielding crop varieties in conjunction with more energy-intensive mechanisation, irrigation and fertiliser use. Uses of agricultural tractors have grown worldwide. The tractor population / '000 ha of cultivable land in the world has stabilised at 19.2 tractor/'000 ha of cultivable land by 2001. In India, the figure rose from 3.7 in 1981 to 15.8 in 2000. This is lower than the world average (19.2), even than countries with transition economies (16.9), and significantly lower than developed countries (31.7).

Indian Production Agriculture

Indian agriculture comprises of a number of production activities (crop, dairy and poultry, fisheries, sericulture, bee-keeping, etc). However, crop production, with large volume, requires most of energy in their production as compared to other produces.

India is blessed with a land area of 329 Mha of which 142 Mha is cultivable. Agriculture has been traditionally the livelihood of majority of its population. Presently about 68% of the work force remains dependent on it. The cultivable area was distributed among 97.16 million holdings in 1985-86 and estimated to be over 125 millions by 2000-01. The average holding size of farms was 2.26 ha in 1970-71 which reduced over time to 1.41 ha by 1995-96. India possesses 16% of the world's population but just 4% of its water resources. Agriculture accounts for about 85% of the total water consumption in the country. The net irrigated area has increased from 20.85 Mha in 1950-51 to 55.14 Mha in 1996-97. With increased uses of inputs, irrigation, improved technology and energy the food grains production has increased from 51 Mt in 1950-51 to 212.05 Mt in 2003-04. In terms of energy inputs/gross cropped area, energy from fertilisers has increased from 584 MJ/ha to 3672 MJ/ha, seeds from 2 MJ/ha to 9 MJ/ha and agro-chemicals from 10 MJ/ha to 17 MJ/ha during 1970-2002. The total energy from agricultural inputs has increased 6.2 times in 32 years, mostly due to chemical fertilisers.

Growth in Farm Power Use

Efficient use of the inputs can be effected through proper and timely completion of farm operations by adopting appropriate farm equipment operated by human, animal and mechanical power. Farm mechanisation in India grew slowly in the beginning, and then accelerated from the Green Revolution (1965) onwards due to an increased need for timely completion of field operations and better utilisation of inputs. Indian farms had only 0.295 kW/ha in 1971, dominated by animal power (45.3%), and is expected to reach 1.50 kW/ha by 2005. Punjab has 4.7 kW/ha while Orissa has only 0.39 kW/ha of power, reflecting the wide variation existing across the country. The share of human power continuously declined from 15.1% in 1971 and reached 6.5% by 2001. The contribution of draught animal power witnessed major decline from 45.3% in 1971 to 9.9% in 2001. The increase in power has been mainly through introduction of tractors, whose contribution has increased from 7.5% in 1971 to 42% in 2001.

Indian agriculture mostly uses small to medium size general purpose tractors with power ratings ranging between 15 kW to 37.5 kW. Wide variation exists amongst the states in terms of tractorisation intensity, ranging between 0.9-71.4 tractor/'000 ha. The highest intensity is in Punjab (71.4) followed by Haryana (60.1), Uttar Pradesh (28), Tamil Nadu and Gujarat (12.3) and Rajasthan (9.8). Agriculturally underdeveloped states like West Bengal and Orissa have tractorisation intensity of 1.5 and 1.3 respectively. Use of high yielding varieties and increasing cropping intensity since Green Revolution had added demand on water requirement. As a result, the share of stationary power had increased from 31.9% in 1971 to 41.1% in 2001. These changes hav made agriculture more dependent on commercial energy sources.

Energy Consumption Pattern

The total energy consumption in production agriculture increased from 5440 MJ/t in 1970 to 11391 MJ/t in 2003. The operational energy also increased from 4531 MJ/t (33.3% of total energy) in 1970 to 7935 MJ/t (69.7% of total energy) in 2003. The share of fertiliser energy increased from 16.4 to 30.1%, electricity from 0.19 to 42.4% and diesel from 2.4 to 10.6%. On the other hand, the share of human energy decreased from 36.7 to 9.4% and animal from 43.9 to 7.3%. The ratio of direct commercial (diesel, electricity)/ indirect (seed, fertiliser, manure, agro-chemical) energy use increased from 0.16 in 1970 to 1.0 in 1980 and 1.74 in 2003, reflecting the increasing role of mechanisation in Indian agriculture which required 42.8 times increase in direct commercial energy use between 1970 and 2003. Indirect energy use increased 3.8 times per tonne of produce during the period.

The gross sown area in the country showed increasing trend to 193.03 Mha in 1998-99 and subsequently followed decreasing trend to 187.94 Mha in 2000-01. The energy consumption, consequently, peaked in 1998 (total energy use of 13414 MJ/t, operational energy use of 9073 MJ/t) and subsequently decreased due to reduced consumption of direct commercial energy (mainly electricity) as well as indirect commercial energy (mainly chemical fertiliser). The ratio of direct commercial/indirect energy peaked to 1.83 in 1998. The total energy required for producing 1 tonne of food increased by 5951 MJ, and operational energy by 3404 MJ, in 33 years for increasing crop productivity by 0.474 t/ha. Total energy use in production agriculture has increased mainly in areas shifting from traditional animal farms to mix or tractor farms. Areas achieving simultaneous increase in crop yield (as wheat, paddy, sugarcane) generally required higher energy investment for enhanced crop inputs. In high crop yielding areas, crop yield has generally increased. Energy productivity has consequently increased in areas where energy resource management has been positive. In other areas, increase in crop productivity has not been generally commensurate with the increase in energy use. The present trend of tractorisation, use of irrigation and fertiliser suggests that energy intensity in crop production would further increase in the future.

Energy Use in Different Crops

Among food grain crops, wheat and paddy are high energy consumers due to relatively high fertiliser use and irrigations provided in majority of the areas. As compared to paddy, maize with 22.4% of area being irrigated requires 76% of energy and sorghum with 92% area under rainfed cultivation, consumes about one-third of energy. The pulse crops with 87.5% of area being rainfed, consume 3870-5464 MJ/ha, less than 50% of that for wheat and paddy. The oilseed crops also consume lower energy in the range of 6382-8051 MJ/ha. Cash crops like sugarcane and potato are high-energy consumers due to high fertiliser and irrigation energy use. Due to high crop productivity, cash crops like sugarcane and potato have high energy productivity (1.039 kg/MJ, 0.495 kg/MJ respectively). The food grains have higher energy productivities than oilseeds and pulses. Among them, paddy and wheat receive higher inputs in majority of the areas resulting into better energy-use efficiencies causing higher crop productivities than those for coarse cereals. Most of the pulses and oilseeds have low energy productivities due to inadequate cultivation inputs leading to low crop yields. The crop productivities of the major crops in India are lower than some of the Asian countries. Increases in crop productivities in India, driven by future food demands, would require higher energy investments.

Farm operations in the country presently consume 37-62% of total energy (other than potato and sugarcane) used in cultivation of different crops, the extents depending on the patterns of energy spent on tillage, irrigation, harvesting and threshing operations. Generally, for irrigated crops irrigation, tillage and harvesting/ threshing are high-energy consumers while for rainfed crops tillage, weeding, harvesting/ threshing are energy consumers.

Estimates indicate that about 30% of the cropped area in the country has presently accepted mechanisation to different extents. The consumption of direct commercial energy resources has thus grown over time. Areas having electric supply prefer it for stationary operations like irrigation and threshing. Accordingly, sugarcane, wheat and potato are major consumers of electricity while potato, sugarcane, wheat, paddy, maize and mustard require significant quantity of diesel. Paddy and wheat cultivations presently consume highest diesel (1.5 and 1.26 million tonnes, respectively). Electricity consumption is the highest for wheat cultivation (5939.7 million kWh), followed by paddy (4228.3 million kWh) and sugarcane (1830.7 million kWh). With increased timely availability of electricity, consumption of diesel for irrigation can be expected to decrease.

Scope of Energy Savings

Studies indicated that generally less than 15% of the farmers use their resources efficiently within the domains of present cultivation practices. Optimal use of energy resources under business-as-usual cultivation can generally provide savings in energy consumptions with simultaneous increases in crop yields leading to better energy-use efficiencies. Areas already adopting better cultivation practices (as Punjab, western U.P.) have lower scope of energy savings (generally less than 10%), but have scope to increase crop productivity by a larger (generally up-to about 45%) extent with optimal energy resource usage. Areas still continuing with traditional practices, especially rainfed, have higher scope of increasing energy efficiency as well as crop yields as being obtained in efficient farms. Farms using only animals have large variation in energy resource usage as compared to mix farms or farms using only tractor/ power tiller, leading to higher scope of better management of energy resources.

With adoption of improved cultivation practices, crop yields can be further increased, generally with additional energy investments, leading to higher energy-use efficiencies. Using animals and tractor/ power tiller for farm operations would generally require higher additional energy investments than farms presently using tractor/ power tiller alone due to required shift to higher uses of mechanical power sources. Since use of draught animals in Indian agriculture would continue in future, the trend of shift to mix farms would prevail and better energy management of these farms would be important. The common major means of increasing energy productivity are:

- Adoption of judicious seedbed preparation practices
- Reallocation of fertiliser (N:P:K) application rates by adopting efficient methods/ practices
- Better water management, reduced use of pumps (especially electric motor operated in areas with subsidized or free electric supplies)
- Use of energy-efficient equipment and practices for tillage, weeding and harvesting/threshing

The characteristics of energy productivities at different levels of crop productivities indicate that highest energy productivity is obtainable at a yield level that is lower than the peak value. With better management of energy resources than presently being used by the majority of farmers, scope exists for increasing productivity of most crops without sacrificing energy efficiency.

Future Issues

Available indicative food production target of India for 2012 is about 300 MT. The productivity of rainfed areas has not been increasing, and would require to be enhanced through improved technologies. Indian agriculture would be moving towards commercialisation, and its growth will depend upon global competitiveness in production costs and quality assurance. Machinery use would increase in the process. Irrigated areas provide 30-36% higher yield, and total area would increase with simultaneous increased demand of water. Potential exists for increasing the productivity of water in agriculture by raising crop productivity, combined with better water management. Power intensive operations like land levelling and deep soil chiselling would increase demand of commercial energy sources. Some estimates indicate that about 50% of Indian population will be living in the urban areas by 2020. Draught animal population is likely to reduce over time. The average farm power availability to agriculture is estimated to be required to increase from 1.5 kW/ha to at least 2 kW/ha by 2020 and 3 kW/ha by 2030 through introduction of tractors, power tillers, self-propelled machines, engines and electric motors. High capacity and precision equipments for seedbed preparation, planting, irrigation/drainage, plant protection, harvesting, threshing for irrigated and rainfed areas will be required. Shift to more mechanical operations would increase commercial energy demand.

Few issues required for increasing energy efficiency of crop production system of the country are outlined:

- The pace of increases in crop productivities in farms is expected to increase with consequent rise in energy demand. Energy productivities of different crops have been varying in different regions of the country. Scientific investigations are required for systematic and periodic generation of real-time databases under field conditions on the dynamic energy use scenario and trace the patterns of energy intensities achieved in different regions of the country.

- Small segment of farms have been able to operate at good energy efficiencies. With introduction of improved implement/ self propelled machines/ technologies, they will require to be periodically evaluated for assessment of energy implications. Optimal energy resource allocations in farms, considering energy costs, would increase energy efficiencies. Detail scientific studies would enable identifications of desired energy resource-mixes, which can be translated through extension agencies.
- Indian agriculture being disaggregated in nature, importance of energy management has not found proper recognition. With increasing demand on commercial energy resources in production and processing of agro-produces, energy management would play a key role in developing regional/ national coherent and implementable strategies for energy conservation and determining appropriate energy resource-mix of conventional and renewable energy resources for minimising energy cost.

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3. Energy Use and Issues in Indian Agriculture

Nawab Ali

Introduction

Agriculture, horticulture and forestry are the major activities which convert solar energy into biomass for use as food, feed, fibre, fuel and inputs to many other economic activities. Renewable energy in the form of sunshine, wind, flowing river streams and biomass have traditionally been used as major sources of energy for carrying out various domestic, community and production activities. Since the middle of 1960s, commercial sources of energy like electricity, diesel, petrol, etc. have gradually replaced the traditional sources of energy to a large extent. The country is struggling with the problem of shortage of grid power. The rural sector has been the worst sufferer. The situation is unlikely to improve in near future. Besides, unprecedented increase in prices of crude oil have compelled India and other countries to vigorously pursue measures for conservation of the petroleum fuels by increasing their use efficiency and also develop their suitable substitutes using indigenously available resources. Among various renewable sources of energy, biomass, which is produced right in the villages offers ample scope for its efficient use to carry out domestic, production agriculture, livestock raising and agro-processing activities through thermal and bio-conversion routes.

It has been estimated that about 65-75% of the total energy consumed in rural sector is for domestic activities. Among domestic activities, cooking consumes around 70-80% of the total energy consumption. Important sources of energy used for cooking are bio-fuels such as wood and twigs collected from forest, road side plantations, etc.; crop residues and cattle dung cakes. Most of the bio-fuels are still burnt in low efficiency smokey stoves. A large fraction of rural houses still use kerosene for illumination. Women in large number of villages still fetch water from wells/ ponds and domestic fuel from nearby forest/road side plantations, etc. Processing activities in rural India is confined to wheat grinding, rice milling and oil expression and domestic level drying of some vegetables, spices, etc. There is a need of having continuous supply of electric power to rural sector for diversified activities leading to employment and income generation. Biomass based decentralized power generation is one of the alternatives.

Farm Power and Energy

Indian farms had only 0.3 kW/ha power source in 1971, dominated by draught animal power (45%). The contribution of different power sources to the total power changed with time and the share of power from agricultural workers continuously declined since 1971-72 and it is expected to be 6% by 2005-06. The increase in total power has been mainly through introduction of tractors, whose contribution has increased from 7.5% in 1971 to 47% in 2005-06. Use of high yielding varieties, increasing cropping intensity since Green Revolution had added demand on water requirement and the share of stationary power had increased from 32% in 1971-72 to 41% in 2001-02. Adoption of diesel engines was most prominent during the seventies. The contribution of electric motors has been consistent over the years with its share increasing from 14% in 1971-72 to 21% in 2005-06. Tractor density is the highest, 72 tractors/1000ha, in Punjab and the lowest is in Orissa, one/1000ha, and mainly used for ploughing, sowing and haulage. The average farm productivity has increased with increase in farm power availability.

The use of farm machinery depends upon the farm power sources available for various tractive and stationary operations. Human and animal power sources have traditionally been used for various farm activities. With increased costs of inputs, high capacity power operated equipments are required to ensure precision and timeliness in operations. Mechanization has become a necessity to reduce drudgery in farm operations specially to women farm workers. These equipment require fossil fuel. Since petroleum is largely imported and electricity being costly, effort are on to conserve commercial energies by supplementing and substituting these with new and renewable sources of energy.

Operations like digging, clod breaking, sowing, interculture, harvesting, threshing, cleaning and grading are still performed by human power (39% being women) using traditional tools and implements, specially in hilly areas. Improved tools have also been developed and commercialized. R&D efforts are on towards converting hand held/ manually guided to engine operated farm equipments to modernize farm operations. In addition, human power is also utilized in the animal husbandry and fishery sector. The work output of the workers can be improved by utilizing ergonomically designed tools and by providing comfortable environment.

Traditionally, draught animals have been used in India for field operations, transport and agro-processing. India possessed the finest breeds of draught animals but concerted effort has not been made to upgrade the local progenies. There are about 79 percent of small and marginal farmers with small land holdings and resources who continue to rely on draught animals and human power for farm operations specially where alternate job options do not exist. Even today, it is estimated that more than 57% area is commanded by draught animals with 2.5 ha command area per animal pair. Field operations in hill regions, *Diara land* and *Tal land*, can be performed only by human and animal power due to difficult terrain.

Energy Use in Agriculture

Energy use patterns of a crop differ with the type of farm power use, extent and type of irrigation, input used, type and extents of farm operations. The national weighted average scenario based on different cultivation practices in the country indicates that among foodgrain crops, wheat and paddy are high energy consuming due to relatively high fertilizer use and irrigations provided in majority of the areas. Cash crops like sugarcane and potato are high energy productive (1.039 kg/MJ, 0.495kg/MJ respectively). The food grains have higher energy productivities than oilseeds and pulses. Farm operations in India presently consume 37-62% of total energy used in cultivation of different crops. However, the extents depend on the energy spent on tillage, irrigation, harvesting and threshing operations.

Estimates indicate that about 30% of the cropped area in the country has presently accepted mechanization to different extents. Areas having electric supply prefer it for stationary operations like irrigations and threshing. Sugarcane, wheat and potato are major consumers of electricity while potato, sugarcane, wheat, paddy, maize and mustard require significant quantity of diesel. Traditional agriculture requires low energy investment but provides low crop yield. With increased adoption of better technologies, energy requirements increase at a faster rate than corresponding increase in crop yield. Proper management of investment of energy resources, however, can reduce the difference in energy efficiency. Studies indicated that generally less than 15% of the farmers use their resources efficiently within the domains of present cultivation practices.

Energy from Renewables

Large varieties and quantity of crop residues burnt in the field after harvest, creating serious air pollution and resulting in loss of soil organic matter, could be utilized for decentralized power generation. Secondary crop residues like bagasse and rice husk are presently used to generate power through steam route. Gasification and fast pyrolysis offer a vast potential to convert surplus crop residues into fuel gas and liquid fuel.

There is need for a development model which integrates biomass based decentralized power generation (DPG) potential of the agricultural production catchments with their overall social and economic development plans and programmes. The R&D support in the field of renewable energy now available is not sufficient to take the laboratory and bench scale techniques to the pilot scale stage at which new developments should be tested for successful demonstration and confidence generation. It is not only the technical performance of a DPG system that will decide its success but the large number of other factors like arrangements for biomass supply, marketing of power and compost, power plant operation and maintenance, match up of supply with demand and financial management will play important roles in deciding DPG's ability to contribute to the cause of rural development. It will be advisable to test the model of integrated energy supply and rural development with focus on biomass based decentralized power generation and agro processing on pilot scale in two or three selected agricultural production catchment.

Energy sources like solar, wind and biomass have potential to be utilized as supplementary energy source. Biomass and animate power meet the major energy needs of the rural sector as it is available locally. The decentralized production of electricity using aero-generators, mini and micro hydel power plants in hilly regions, photovoltaic energy for lifting water, lighting, energisation of household appliances and in communication are now economically feasible. It is estimated that more than 600 million tonnes of biomass is available from various crops residues and agro-wastes. 35-40% of biomass is utilized for animal feed and the remaining as energy source through direct combustion either for cooking food or for processing of agro-produce. About 30 lakh biogas plants have been installed up to the end of 1999-2000 which are estimated to generate fuel gas equivalent to the saving of about 30 lakh tonnes of fuel wood per year. Besides, these plants are generating enriched organic manure containing nitrogen equivalent to about 8.5 lakh tonnes of urea per annum. A total of 32 million improved *chulhas* have been installed till the end of 1999-2000 and are expected to save over 10 million tonnes of fuel wood per annum.

Energy Autonomy Potentials

Energy autonomy potential (EAP) of two major crops, rice and groundnut, based on their byproducts (husk & shell) for a 2t/ha rice mill and one t/h oil mill has been worked out at SPRERI, Anand. India produces about 140 Mt of paddy and 7.5 Mt of groundnut annually. Paddy yields 18% husk and groundnut gives 30% shell in milling. The rice husk obtained (360 kg/h) from 2t paddy/h rice mill will produce sufficient gas to generate either 130 kW power or 50 kW power and 900 kg steam. This estimate is based on the modest assumption that gasification efficiency is 50% and all gas gen-set efficiency is 20% and 1 kg husk can produce 4 kg steam. A one t/h groundnut oil mill producing filtered oil can have 200 kg available as fuel. It is enough to generate 80 kW power and 200 kg steam assuming 60% gasification efficiency, 20% all gas gen-set efficiency and 5kg steam/ kg shell.

India has about 30,000 modern rice mills and 600-700 groundnut oil mills. Creation of energy self sufficiency in 10% rice mills and 20% groundnut oil mills will add about 150MW to the biomass based renewable power generation. If 50% of the rice mills and most of the groundnut oil mills start using husk and shell for power generation, 700 to 800 MW will be added to the renewable energy generation capacity. The cost of one kWh energy will be between Rs. 2.4 to Rs. 3.7 assuming the husk/shell price to vary between Rs. 500 to Rs. 1000/t. CO_2 credit will further reduce the cost. The use of husk and shell will impact autonomy and security to rice and groundnut oil mills.

The merits of agro-industrial development in production catchments have been recognized for many years. However, with the exception of sugar mills, progress on the ground in terms of agro-industries coming in the rural areas has been negligible. Assured supply of good quality power is a prerequisite for industrial development. Grid power supply to the rural sector is inadequate, irregular and of poor quality. Unless the issue of power supply for agro-industrialization of the rural sector is properly addressed, the situation will not change.

Biomass is a renewable resource and it is widely available. It is a natural store of energy and it is CO_2 neutral. Surplus crop residues which are now burnt after harvest to clear the land for the next crop are the most sustainable source of biomass. The total amount of crop residues (cereal straw, cotton sticks, sugarcane trash, etc.) burnt in the country each year is estimated at about 70 million tonnes. Crop residues based power generation in production catchments will make the residues a marketable commodity which will bring additional income to the farmers. Air pollution caused by uncontrolled burning will be reduced. The farmers will become the suppliers of fuel and the users of the generated power. This will require a management system which can ensure biomass recovery from different sources and locations, its conversion, and delivery of bio-energy for its end use through a commercially viable energy source. Arrangements will have to be put in places for their timely harvest, collection, densification, transport and storage and delivery to the power plants according to their needs.

Combustion route is widely used to derive heat energy from biomass. Biomass based co-generation plants produce both power and heat energy in mega watt range. Selected crop residues can be converted into energy carriers like producer gas, biogas, bio-oil, alcohol, etc. Techniques to obtain hydrogen from producer gas and biogas are being developed. SPRERI has developed

Table. Some of the energy issues

Source of Energy	Issues involved
Draught Animal Power	• Enhancement of DAP utilization efficiency through appropriate harnesses and matching equipment for different breeds ***(Draughtability, matching equipment and work rest cycle)*** • Expanding the annual use of DAP through haulage (carting) and rotary mode of operation for agro-processing and electricity generation ***(Rotary mode of operation)*** • One pair DAP based optimum farm size and other annual usage for economic viability ***(DAP based optimum farm size)***
Renewable Energy Sources	• Crop residue based decentralized power generation through gasification (flue gases) or anaerobic decomposition (biogas) or fermentation (fuel alcohol). System and gadgets need to be developed tested and upgraded to a pilot plant of an appropriate size. Performance evaluated and management package developed. ***(Biomass based DPG using thermal or bio-conversion route)*** • Promotion of biomass based improved cook stove, solar cooker and biogas & SPU appliances in rural sector ***(RES based gadgets and appliances)*** • Bio-fuel from Jatropha and Karanj for tractor and diesel pump sets ***(Bio-fuel/diesel)***
Conventional Energy Sources (Petroleum)	• Development and promotion of energy conservation technology and maximization of energy use efficiency ***(Energy saving technology)***

the process for solid-state conversion of soft residues like cereal straw and sugarcane trash into biogas and compost. A 10 MW plant based on this technique will require about 1 lakh tonne of rice straw to produce annually about 8 million kWh of electrical energy and 65,000 tonnes of high quality compost. Using SPRERI process half of rice straw burnt in Punjab each year can support decentralized power generation upto 600 MW and yield about 4 million tonnes of organic manure. This is just one example of the scope to use surplus biomass to improve energy supply to villages.

Technology for biomass based decentralized power generation in the range of 25 kW to 10 MW or more is now available in the country and outside. It should be harnessed to provide power in selected agricultural production catchments which have the biomass, mainly crop residues, to sustain power generation round the year and which have the potential for the development of agro-processing and food industries. While the power generation plan should take into account the domestic power needs to the villages in the catchment and the power needs of production agriculture, the focus should be on the development of additional economic activities, particularly agro-processing. It will be advisable to initiate decentralized power generation on pilot scale at 3 or 4 locations to understand the related issues.

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4. Status of Renewable Energy Use in Agriculture and Scope of Future Substitution of Commercial Energy

B.S. Pathak

Introduction

The ICAR has the distinction of being the first to sponsor research on energy needs of a developing agriculture by operating a coordinated project "Energy Requirements of Agriculture Sector" from 1971. After the world energy crisis in 1973 the industrialized countries were the first to apprehend the threat from the continuing depletion of fossil fuel resources, particularly of hydrocarbons and translated into the search for new hydrocarbon resources and for alternatives to hydrocarbons. Simultaneously these countries planned and initiated improving their energy management in all sectors of economic activity including agriculture. India's efforts on similar lines also have been substantial. But its energy security still remains uncertain. Inspite of the continuing increase in installed capacity, shortages in total electrical energy and peak power have become chronic features of our grid power system. With over 70% dependence on imports, India's hydrocarbon supply is vulnerable to disruption caused by events beyond its control. The rising prices of diesel are threatening the survival of thousands of small industries which use diesel gensets and of over six million farmers, mostly in eastern parts of the country, who use diesel pump sets. The growing opposition to the use of coal on environmental grounds and the growing competition for hydrocarbons do not offer much solace to the energy planners and managers of this country.

Energy Consumption in India

India's energy requirement which was about 325 million tonnes of oil equivalent (MTOE) in 2002 is projected to increase to 709 MTOE in 2030. The depleting hydrocarbon resources, the growing demand, competition for these resources and the global pressure to reduce coal use do give a feeling that the estimates are optimistic.

Commercial Energy Inputs to Indian Agriculture

Last 4 decades have seen increasing dependence of Indian agriculture on grid power and hydrocarbon fuels. Published information during the recent years indicate that agriculture consumed 17.18 MTOE of commercial energy (9.2% of total consumption) in 1998-99 which has reduced to 14.72 MTOE (8.6%) in 2001-02. Since the number of prime movers, self propelled machines and irrigation pumps has been growing, a continuous rise in commercial energy consumption is expected. There is a need to improve the reliability of information on commercial energy use in agriculture for its better management and for planning. The energy intensity of agriculture in 2001-02 was 0.032 MTOE/Rs. 1010 GDP compared to the national figure of 0.076 MTOE/Rs. 1010 GDP. Indian agriculture, in terms of GDP, makes the most productive use of commercial energy.

Energy Consumption in the Rural Sector

Information on the energy use/needs for different applications in the rural sector is summarized below:

a) Rural households

About 90% of the 120 million rural households use fuel wood, other woody biomass and dung cakes as the main source of energy for cooking. Biogas is the primary supplier of cooking energy to 0.3% households only. The remaining households use coal, L.P.G., charcoal, kerosene, etc., as cooking fuel. There is unauthorized use of electricity for cooking in some households if unmetered grid power is supplied during cooking hours. Electricity and kerosene are the sources of energy for lighting. In areas not served by the grid and where kerosene supply is inadequate, plant oils are used for lighting.

b) Production agriculture

Production agriculture is the major consumer of commercial energy. Operations like land forming, tillage, planting, irrigation, harvesting, thrashing, and transport are being progressively mechanized increasing dependence on hydrocarbon fuels and grid power, inspite of limited and uncertain supply of grid power and rising prices of hydrocarbon fuels.

c) Rural services

Rural services and utilities in the villages suffer due to inadequate and irregular supply of power. The power requirement of rural services is relatively small but without assured power these services cannot function effectively and efficiently.

d) Agro-processing

The merits of agro-industrial development in production catchments have been recognized for many years. Agro-processing industries require 20-464 kWh/t of mechanical energy and 0.2-1.6 t steam/t of raw material. However, with the exception of sugar mills, progress in terms of agro-industries coming up in the rural areas has been negligible. Grid power supply to the rural sector is inadequate, irregular and of poor quality.

Future Needs of Indian Agriculture (Rural Sector)

Assuming a 3.5% simple overall growth in agricultural inputs, including energy, and using 2000-01 as the base year, the demand for diesel will increase by 1.4 MT and electrical energy by 1.25 MTOE every 5 years. According to another set of data, the need for electrical energy will increase by 14,828 million kWh in 5 years which will be equivalent to 4.5 MTOE. In any case the demand of both diesel and electrical energy for business as usual situation is likely to increase by 100% in 25-30 years. Assuming that agricultural production (including milk) will increase by 100% in the next 25 years and that the added production will be processed in the rural sector, the energy demand for primary processing will be 17,000 million kWh and 45,000 million kWh for secondary processing. The demand for electrical energy to process the added produce will grow at a rate of over 12,000 million kWh/5 years. The energy supply will have to be raised by over 100% in the next 25 years. The quality of power supply will have be much better than power supply for 4 hours only, supply hours change without notice and the voltage fluctuates by 30% or even more. Development of local resources based energy autonomy for the rural sector seems to be the most promising approach to pull Indian agriculture out of this catch 22 situation.

The total capacity of renewable power system in December 2004 was 5594.5 MW (wind turbine accounting for more than 50%), less than 5% of the installed grid and captive conventional power capacity. Availability of wind energy is site and season specific. Linking the installation and management of small hydros with the development of agro processing activities and rural services in the hilly and mountaneous regions deserves priority consideration. Solar photo-voltaic cells (SPV) are a clean and convenient source of renewable energy. It is planned to provide SPV based lighting systems to 18,000 villages which can not be served by the power grid, during the current five year plan.

Biomass is a renewable natural store of energy and is widely available. A large share of the fuel wood supply comes from the forests which need protection and further development. It is improbable that large land area will be available for planting energy crops in India. The energy potential of crop residues like rice and wheat straw, sugarcane trash, mustard stalks, etc., has remained untapped. The production of food grains, oil seeds, fibre and sugarcane increased to 3-4 times during the period 1951-2001 with parallel increase in the production of crop residues (CR); some of which mainly in irrigated areas have become surplus to their conventional use as feed, domestic fuel, industrial feedstock, etc. The farmer has taken to large scale burning of CR immediately after harvest. The agro-processing residues are also an important source of biomass for energy generation. Over 45 million tonnes bagasse (dry basis), 25 million tonnes of rice husk, 2 million tonnes of groundnut shell are more important agro-processing residues. The 70 MT CR and processing residues are equivalent to 45 million tonnes of oil in their heat content. At an overall conversion efficiency of 25%, these biomass sources can sustain 17,000 MW power generation. The increasing surplus of CR and agro-processing residues has the potential to meet the entire energy needs of the rural sector in the years to come.

Sugarcane and plant oils can, if required, meet a major part of the liquid fuel demand of Indian agriculture. A tonne of sugarcane yields 62 litres of 200 proof alcohol. At an average yield of 70 t/ha, 4 million ha of sugarcane can produce sufficient fuel grade ethanol for complete replacement of diesel in production agriculture. It is claimed that a million hectare of Jatropha plantation can produce upto 3 million tonnes of bio-diesel and the 13 million hectares of cultivable wasteland can produce sufficient biodiesel to make us independent from diesel/petroleum imports. Most of these estimates are optimistic but the scope for supplementation is bright.

Slow Rate of Harnessing Renewable Energy Resources

Renewable energy has mass appeal but no mass application. The reasons for its slow acceptance are technical weaknesses, high cost of generation because of small size, low capacity utilization, subsidized fossil fuel prices, inappropriate costing methods and lock-in effect. Renewable energy technology, which was driven by subsidies earlier, has become to a great extent market driven, indicating that technically it has become efficient and reliable.

Biomass the Main RE Source for Indian Agriculture

With non-energy use of crop residue not likely to increase much, a 50% increase in food grains production would render 300 MT biomass (200 MT of surplus CR and 100 MT of agro-processing residues), equivalent to 114 MT oil or 225 MT high ash coal, available for energy generation. This, supplemented with sugarcane derived ethanol and plant oils, can make Indian agriculture and agro-processing industries self reliant in commercial energy, and also make agriculture an important supplier of energy to other sectors.

The characteristics of Crop and Agro-Processing Residues, in their chemical composition, are not different from wood. The main products of combustion of CR are CO_2 and H_2O. Since CO_2 is recycled to produce an equivalent quality of biomass for the next harvest, there is no addition of this greenhouse gas to the atmosphere. However, CR have very low bulk density, poor flow ability, non uniform shape and size and higher ash content compared to wood. Also their availability is seasonal, requiring storage for long period to ensure continuity in supply.

Biomass Conversion Routes

Rich in its carbon and hydrogen content, biomass can be processed to produce energy through different routes as combustion, gasification, pyrolysis, alcohol fermentation, plant oils and anaerobic conversion.

Bagasse has been the main source of heat energy in small jaggery units as well as in the largest of sugar mills. The modern sugar mills have adopted co-generation to produce and supply both electrical/mechanical energy and process steam. The larger sugar mills produce excess bagasse based electrical energy and is fed to the grid. It should be possible to convert all sugar mills in the future into energy self-reliant units.

Rice husk combustion based 5-6 MW fluidized bed combustion units have been established in some states. Procurment of requisite rice husk from small and scattered mills has been difficult. It is not economically feasible to generate power on small scale through biomass combustion route. A cluster of rice mills, milling 20 tonnes of paddy/hr producing 3 tonne husk/hr can generate 1200 to 1500 kW power and supply 12 tonnes of process steam/hr with more than 60% of power and 40% of process steam as spare for other uses.

Gasification of biomass produces producer gas which can be used both for thermal applications and as engine fuel. It burns without smoke. Although most of the gasifier systems developed so far operate on wood, rice husk and groundnut shell have been successfully used. Integrated gasification combined cycle (IGCC) systems capable of gasifying many tonnes of biomass/hr to supply producer gas for generating power in multi MW range have been developed in Europe and North America, and is ideal for biomass based decentralized power systems in the crop production areas to impart energy autonomy to production agriculture and agro-processing.

Pyrolysis is a traditional technology to produce charcoal from biomass. Flash or fast pyrolysis are recent developments, where biomass is heated very quickly to a temperature of about 500°C for conversion of most of the carbon and hydrogen in biomass into a liquid fuel (with more than 75% of heat content of biomass) commonly called bio-oil. Fast pyrolysis is a rapidly developing future technology.

Alcohol fermentation of sugar/starch containing crops and by-products like molasses is a commercial process. A tonne of sugarcane yields 62 litres of 200 proof alcohol which is equivalent to 42 litres of petrol. Two percent of India's cultivated land producing 70 t of sugarcane/ha will supply 12.4 million kl of ethanol sufficient to meet the needs of rural transport, a fleet of 3 million tractors and self propelled machines. Presently 5 to 10% blending of ethanol with petrol has been accepted by many countries for automobile fuel. More R&D is needed for a gradual shift of Indian agriculture from 100% fossil diesel to fossil diesel-alcohol blends.

Most of plant oils, if sufficiently filtered, degummed and dewaxed, can be blended with diesel and used as fuel in compressor ignition engines. Plant oils have very high viscosity and the free fatty acid content goes up very fast under normal storage conditions. These oils have generally been more expensive than diesel. Trans-esterification of plant oils offers a solution to the problems of high viscosity and free fatty acid content. The new esterification processes do not require a catalyst and employ high pressures and temperatures. Bio-diesel can satisfactorily supplement and replace diesel provided the plant oil cost is sufficiently low.

As reported by MNES, 3.7 million biogas plants have been installed and the number is increasing. These can in general meet the limited requirements for fuel of individual households or hamlets. Recently, a process for solid state conversion of soft residues (cereal straw and sugarcane trash) into biogas and compost has been developed. A 10 MW plant based on this technique will require about 1 lakh tonne of rice straw to produce annually about 80 million kWh of electrical energy and 65,000 tonnes of high quality compost. The technology can process half of rice straw burnt in Punjab each year and support decentralized power generation upto 600 MW and yield about 4 million tonnes of organic manure.

Decentralized Power Genertion (DPG) from Biomass

Generation of commercial energy and energy carriers from biomass requires investment on biomass collection, preparation and conversion systems and on power generation and distribution facilities. It also requires management and technical skills. Few energy carriers like ethanol and bio-diesel are the only exceptions because these can be blended with petrol/diesel. The desirable approach would be to organize generation of energy and energy carriers from biomass on commercial scale through private and cooperative enterprises. The DPG systems has to be technically sound. Factors like regular supply of biomass, marketing of power and by-products like compost in one case, match up of generation with demand and financial management and integration with local development plan will play important roles in deciding how effectively biomass based DPG serves the cause of rural development.

Conclusion

1. The rural sector has been poorly served by grid power system. Rural development will continue to suffer unless the energy supply to the villages is improved.
2. Locally available renewable energy sources should be harnessed to improve the energy supply to the rural sector. Biomass (crop and agro-processing residues) is the best source of renewable energy.
3. As the first step, the quantity of surplus biomass available at different locations in the country should be ascertained and the biomass should be characterized for its suitability as source of energy.
4. Decentralized power generation systems, specifically designed to utilize the type and quantity of biomass available at different locations, should be established and given connectivity to the grid system so that the surplus power generated by the decentralized power units is fed into the grid till the local demand develops to utilize it fully.
5. The biomass based power generation plan should be fully integrated with the local development plans.
6. Biomass management technology should be developed and proper arrangements put in place to ensure a smooth movement of biomass from the farmers' fields to the point of its use as energy resource. This will require an efficient system for the recovery, handling, transport, storage and pretreatment of biomass.

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Proceedings of the Symposium on "Statistical and Computational Issues in Rainfed Agriculture"

Chairman : Dr. G. Kalloo
Convenors: Dr. V.K. Gupta
Dr. S.E.H. Rizvi

Six papers covering various aspects related with the theme of the symposium were presented by the following speakers:

1. Rainfed Agriculture: An Overview - presented by Dr. H.N. Khajuria, SKUAST-Jammu.
2. Hill Agriculture: Challenges and Opportunities in Western Himalayan Region - presented by Dr. R.K. Gupta, SKUAST - Jammu.
3. Statistical Designing of Experiment for Hill Agriculture Research - presented by Dr. Rajendra Prasad, IASRI, New Delhi.
4. Small Area Statistics for Agro-climatic Regional Planning - presented by Dr. B.V.S. Sisodia, NDUAT, Faizabad.
5. Statistical Considerations in Agricultural Research under Rainfed Conditions - presented by Dr. N.S. Gandhi Prasad, DPDKV, Akola.
6. Methodological Issues Related to Rainfed Agricuture - presented by Dr. Girish Kumar Jha, IASRI, New Delhi.

The following recommendations emerged out based on the discussions during the symposium:

- Research in statistics should address the issues of socio-metrics and other emerging issues of rainfed agriculture to enhance the productivity and profitability.
- Efficient and cost effective designs should be generated for rainfed & hill agriculture, silvo-pastoral, agroforestry, integrated nutrient/pest/water management, food processing and post-harvest storage experiments.
- The experimental design should be made available online with the E-Advisory Services and discussion forum for experimenters.
- Statistical issues related to farming and other agricultural systems along with economics of the system should be addressed with emphasis on rainfed agriculture.
- Machine learning techniques like neural networks, rough set theory, fuzzy regression, genetic algorithms etc. should be used for forecasting crop yield using agro-metrological data and fore warning of pests/ diseases.
- Databases should be created for barest minimum requirement for soil, crop, environment, bio-resources, weather and disaster management etc. and used for planning the appropriate technological interventions for rainfed agriculture.
- Remote sensing techniques should be augmented with ground survey in GIS environment for collection of available agricultural statistics in rainfed regions.
- Statistics should take a lead in generating sophisticated analytical techniques and interpretation of data related to functional and structural genomics.
- The existing know how should be mixed judiciously with the modern technologies to address the important issues of rainfed agriculture particularly with respect to enhancing the productivity and profitability.

- The technology development programs should also be directed towards rainfed agriculture so as to enhance the economic condition of poor farmers in rainfed areas.
- Some key areas like selection of suitable crops/ varieties, watershed management, organic farming, efficient resource use, soil and moisture conservation and development of pastures need due attention for up gradation of rainfed farming.

1. Rainfed Agriculture: An Overview

H.N. Khajuria

The agriculture continues to be a major mainstay of Indian sub-continent. In India, huge population i.e. 16 per cent of world's total human population and 30 per cent of cattle population is accommodated on 24 per cent of the land area with 40 per cent of the water resources. The agriculture development in the last live decade or so has recorded remarkable growth surpassing population growth. The ushering of green revolution followed by white revolution, blue revolution, brown revolution or so-called rainbow revolution transformed the once food deficient country into surplus State. Also, enabling the country to export of food-grains and other agricultural products.

The above scenario is currently under threat as the agriculture growth is not keeping pace with population growth. Further, under WTO and the GATT regime, coupled with maintenance of quality and pressure pertaining to subsidy in agriculture, the problem of sustainable growth has been further accentuated.

It is worth mentioning that the remarkable growth, which the agriculture has achieved, is primarily on account of development under irrigated sector. The resource inputs both with respect to human resources as well as physical resources including development of crops/ varieties, improvement in irrigation technology, seed production and fertilizers application have been towards irrigated land. Even the emphasis with respect to research and development in agriculture machinery has been towards irrigated land. The rainfed areas have almost remain excluded with comparatively less attention paid therein. This is evident from the fact that where the productivity per unit area in a unit time has been comparable to the world average when compared with irrigated lands, but when total production is taken into account including that from rainfed areas, the country stands far behind with its rank as 32nd, 35th, 118th, 50th, 34th and 57th in wheat, rice, pulses, groundnut, sugarcane and cotton respectively. This primarily can be attributed to low productivity per unit area under rainfed agriculture.

Rainfed farming is therefore, to be considered as a key priority area. About 66 per cent of the cultivated area of the country is under dry land farming but accounting for only 45 per cent to its national food basket. This abviously affect the income of the farmers also, and by and large they have not been benefitted by green revolution ushered in sixties. There are number of problems which are faced by these farmers including uncertain monsoon, frequent drought, degraded soils and socio-economic factors like small holdings, poor infrastructure, poor credit flow inability to invested in crops/animal husbandry including fertilizers, pesticides, weedicides, application of machinery etc. Since agriculture is not remunerated, most of these farmers go in for alternative sources of livelihood, specially rearing of livestock. Here also, they have problems with respect to shortage of green and dry fodder and poor quality of grazing land.

This symposium on statistical and computational issues on rainfed agriculture, has been organized by the Indian Agricultural Statistics Research Institute. These issues may be taken upon priority. Even the information pertaining to status of rainfed farming across the country with respect to inputs credit flow, outputs, benefits accruing from various government sponsored schemes is not available. Economics studies on natural resources management in these areas, research and development inputs from engineering sector, health and status of livestock is still not properly documented, which would make the basis for the future management strategies.

Some of the key areas, which need to be addressed for up-gradation of rainfed farming, are listed as under:

1. Selection of Suitable Crops/Varieties

In contrast to the crops suitable for irrigated farming, the emphasis is required to be laid on selection and improvement in crops and its seeds, which are suitable for rainfed farming. The core cereals, pulses, oil seeds under crops and fruits like lemon, guava, ber, pump-grenate etc. can be taken-up. Specialized human resource capital needs to be developed to take up such projects.

2. *Watershed Management*

Although there are number of schemes in operation since long, which deals with watershed management across the country, the actual success and the benefits derived there from need to be documented, and further refinement if required must be made so that rainfed farming gets benefitted. The micro watersheds may also prove beneficial to the farmers by way of providing at least life saving irrigation.

3. *Development of Matching Agricultural Technology*

In many states there is a package of recommendations in respect of various crops and seeds. However, major component of these recommendations are not applicable to dry land farming and hence this sector is not getting the benefit there off. In states like Jammu and Kashmir where 75 per cent of the area is under dry land/rainfed farming, the major input with respect to the establishment of research station and development of technology is require to be attracted towards these goals.

4. *Research and Development in Agriculture Machinery*

Revolutionary development leading to use of tractor, combine harvester, multipurpose seed driller have no doubt contributed towards agriculture production but hardly, the benefits of all these developments have gone to the farmers operating under rainfed and dry land agriculture. The reasons being obvious. Nevertheless they deserve to have the benefits of agriculture engineering by way of development of suitable machinery/ implements as per the needs of the system. Institutional arrangements are required to be made.

5. *Efficient Resources Use*

As we understand the resources available with dry land farmers are not sufficient, the efficiency in their use is require to be optimized. As of now only 35 per cent is the efficiency of fertilizer use in rainfed areas in contrast to 40 to 45 per cent in irrigated areas. This requires manipulating in various agro-technology interventions including split applications, use to nitrification inhibitors, application of organic coating etc.

6. *Development of Allied Sectors*

As already pointed out whether productivity in agricultural crops under rainfed conditions is low the income/livelihood of the farmers keeping improvement by way of adopting other enterprises such as dairying, fishery, apiculture, poultry, sericulture, piggery, rabbit farming, mushroom cultivation etc. The present status in respect of all these sectors is required to be brought out with specific benefits accrued in rainfed farming till date. A complete document is required to brought out on this issue.

7. *Organic Farming*

We can appreciate that there is minimum use of chemicals including pesticides, fertilizers, weedicides etc. under rainfed farming system. Sine there is huge potential of organic farming or value addition, special initiatives/ schemes are required to be formulated for this area.

8. *Soil and Moisture Conservation*

Technology with respect of tillage and use of mulches is more relevant under rainfed system, the project at national/ state level with this objective in focuss is required to be taken up accordingly, since especially the sowing time is very narrow, this gains special significance.

9. *Development of Pastures*

Since major component (two third of the total) of livestock is raised by these farmers to help to maintain their livelihood, hardly major efforts are made for the improvement of grazing lands and livestock health. A number of silvi-pastoral system are therefore required to be standardized to help to bring improvement in this sector.

Conclusion

At the end I will conclude only with one sentence that the time has come rather it is overdue that these farmers operating under rainfed/dry-land farming are paid due attention to facilitate their logical right for better/ improved livelihood. And the first step in this direction will be to document the related issue for further planning.

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2. Hill Agriculture: Challenges and Opportunities in Western Himalayan Region

R.K. Gupta

India is the land of diversity with lofty Himalayas and the great central plains. The urban civilization first emerged in the valleys of the rivers coursing down from the Himalayan Mountains. Hill and mountainous areas in India are distributed all over the country with larger areas in Himalayas, extending in 2,500 km length and 250 to 400 km breadth. Himalayas are characterized as Shivaliks (flat summits 600-1200 mamsl), middle Himalayas (average altitude 3000 mamsl), greater Himalayas (average altitude 5200 mamsl) and trans Himalayas (average altitude 4500 mamsl). These areas can be classified into nine regions, (1) Western Himalayan region, (2) Eastern Himalayan region, (3) Eastern Plateau hill region, (4) Central Plateau hill region, (5) Western Plateau hill region, (6) Southern Plateau hill region, (7) East Coast hill region, (8) West Coast hill region, and (9) Gujarat hill region. These regions exist all over the country and cultivation is on terraced fields.

The hill and mountain agro-ecosystem differs from plains in topography, elevation, climate, farming system and socio-economic conditions. Majority of areas in the region suffer from harsh environmental impacts like deforestation and are highly prune to run-off, soil, wind erosion and nutrient loss. These regions having wide range of harsh climatic conditions and fragile ecosystem remained deprived of the benefits of green revolution. Majority of farmers are small and marginal. There is huge gap between actual and potential yields. Majority areas are still deprived of new varieties/technological interventions for various reasons. Poverty, hunger and insecurity still cripple the life of people in these disadvantaged areas that often remain neglected. Droughts, untimely snow/rainfall and other natural calamities (including earthquake) adds to starvation and deaths.

Agriculture continues to be the backbone of the Hill States food, livelihood and ecological security. This security can be achieved through the sustainable and profitable farming systems, happy rural and farming families, and balanced diets and safe drinking water for all. India supports 16% of world's population while using 2.3% of world's land and 4.25% of water resources. Per capita availability of land is also 4-6 times less as compared with world average. Out of 329 m ha geographical area, around 142.5 m ha (47%) is cropped area and around 65% of this cropped area is under rainfed farming. The availability of water for agriculture is also coming under increasing stress in near future. Per capita available land is also likely to decrease from 0.163 ha in 2000 to 0.121 by 2025. Input-driven technologies have improved production making India self sufficient in food-grain production but questioned sustainability of production and natural resources. The yields in rainfed areas in hills are generally low and unstable. Absence of organized irrigation make hill farming with seasonal crops uncertain in specific farming situations.

Hills offer a vast potential for cultivation of wide variety of crops and animal husbandry is an integral part of farming system. Temperate climatic condition allow cultivation of some fruits, vegetables, spices & condiments and herbs otherwise not possible under plains. The North-Western Himalayan region (NWH) consists of Jammu and Kashmir, Himachal Pradesh and Uttranchal. The sub-agro-climatic zones in general can be classified into (1) Low altitude/sub-tropical zone, (2) Mid to high altitude intermediate/subtemperate/sub-humid zone and (3) High hills temperate zone (wet/dry). The diverse agro-climatic conditions of NWH region in general and Jammu & Kashmir in particular with most of area as rainfed, allow cultivation of wide variety of crops (maize, millets, oilseeds, pulses); fruits (ber, aonla, guava, apple, mango, walnut, olive, wild pomegranate); spices and condiments (saffron and kalazeera); and herbs. The region is also rich in plant genetic resources of valuable species and the quality of produce is exceptionally good. The livestock rearing provides subsidiary occupation to drought prone/rainfed areas in hills where crop production is not economical.

Ever increasing population demands increasing both production and productivity in sustainable manner under shrinking land, water and bioresources. There is scope for vertical expansions through synergy among technology, public policy, people's participation and adoption of an integrated approaches. Important considerations include:

- Mapping of bio-resources, conservation and their judicial exploitation.
- Productivity and quality revolution through eco-friendly technologies.
- Efficient utilization of technologies including watershed development rain-water harvesting and micro-irrigation.
- Replacement of old varieties with improved ones in specific agro-climatic situations with due emphasis on horticultural crops.

- Sustainable management of natural resources through development modules for integrated water, pests and nutrient management in specified crops.
- Diversification through integration of bee-keeping, sericulture, livestock, sheep and goat rearing and fishery.
- Value addition through on-farm storage and post-harvest technologies.
- Promotion of farming in nitch areas (organic, off-season and protected cultivation, high quality temperate seed production.
- Use of remote sensing, geographic information system and distant learning in remote and inaccessible areas.
- Empowerment of women in decision making and transfer of technology.
- Harmonization of traditional knowledge with modern technological interventions through appropriate policies and institutional support.
- Development of disaster-management modules for drought, excessive snow/rainfall and other man-made/natural calamities.

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3. Statistical Designing of Experiments for Hill Agriculture Research

Rajender Parsad and V.K. Gupta

Experimentation is an indispensable component of every scientific endeavor and designing an experiment forms an integrated and important component of every research programme. Designed experiments are conducted extensively under National Agricultural Research System (NARS) comprising of various ICAR Institutes, National Research Centres, Project Directorates, State Agricultural Universities, etc. It is through the data collected from designed experiments that valid inferences are drawn. Therefore, in order to maintain high standards of research and to make quality of agricultural research globally competitive, it is essential that sound statistical methodologies be adopted in the collection and analysis of data and then interpretation of results. In any designed experiment, there are two major sources of variability. One major source of variability is the treatments used in the experiment and the other major source of variability is the experimental material on which the experiment is conducted. An efficient experimental design for a given problem takes care of the variability present in the experimental material. Hilly regions suffer from many problems like run off, soil erosion and nutrient loss, small highly variable and sloppy fields. Valley and foothill of Himalaya have partial irrigation facilities. Therefore, most of the agriculture is rainfed in the region. Designing experiments for rainfed agriculture and hill agriculture research, consequently, needs special attention because of the nature of the variability present in the experimental material.

Hill agriculture consists of small highly variable fields (commonly prevailing size is 80-100m^2 to 200m^2). The management of natural resources like soil, water and utilization of land in hills has to be accommodated with terrain conditions, unlike in plains where plots can be made or cut according to the requirement. For example, 3 nutrients/mulching/irrigation management when studied as main plot treatments, have to be laid out within three or four drainage systems. These can be considered as micro-watershed and entire plot is naturally drained by a common drain or small "Nala". In such situations considerable variability exists within upper reach to middle to lower reaches or terraces. Variability arises mainly because of runoff and soil loss from upper terraces that add to middle and lower terraces. Now the variation or phenomena have to be accommodated while scaling up the research data from field plot to an area scale. This factor is significant in hill terrains compared to the plains. The purpose of this talk is to highlight the potential and the usefulness of some efficient designs generated in the literature in hill agricultural research. We shall also make a reference to rainfed agriculture as well during the presentation. The presentation being made here derives its strength essentially from the exposure gained through the advisory services rendered to the agricultural research personnel.

In hilly areas, the experiments are conducted on terraces. Different terraces are considered as natural blocks and plots on each terrace are considered as homogeneous. However, each terrace may not be of the same size. Further, if the blocks are formed on the same terrace with levels of depth of soil as blocking factor, then it may not be possible to find the same area for each soil depth. Therefore, the question is "What are efficient designs for such experimental situations. One possible solution for this is to make use of block designs with unequal block sizes.

Although designs with unequal block sizes are useful for experiments in which the terraces are taken as natural blocks, it may so happen that there might still be variability within the long terraces because of soil depth, runoff from upper reaches to middle or lower reaches, etc. If this variability is not controlled then this may also lead to less precise comparisons among the treatments. Therefore, to take care of heterogenity within in terraces, the blocking of experimental units within terraces is required. For such experimental situation, nested block designs can be quite useful. A nested block design is a block design where another source of variation is controlled by forming sub-blocks within each block of design.

Although nested block designs take care of the variability present within the terraces, there might be more than one source of variability within the terraces viz., the soil depths, soil fertility, soil texture, etc. These sources of variability form a crossed classification within the terraces that are the big blocks. Block designs with nested rows and columns are useful for such experimental situations. It is indeed possible that the terraces have unequal number of plots within them and, therefore, the terraces cannot or need not be divided into equal number of rows and equal number of columns. Another serious problem while experimenting in hilly areas is that the blocks farmed are physically separate fields (say, different farmers' fields), some blocks in the large plain field and some in the terraces in the hilly areas. In hilly areas when some fields are on the plains and some are on the hilly tracks it may happen that the number of plots within the fields may vary widely. For instance, the number of experimental units in the fields in the plain may be quite high while the number of plots possible on the fields that are the terraces in the hills may be very small. The block designs with nested rows and columns with unequal block sizes may be quite useful for these situations.

Further, in hilly areas, different dulations of land are taken as blocks and the number of plots in a level is the block size. The number of plots in each block may or may not be equal because of limited available land in a particular dulation. Moreover different levels may be little sloppy due to hilly area and this may cause trend effect due to movement of nutrient in one direction or different soil depths, etc. In such situations, a common polynomial trend of a specified degree over units within experimental units may be appropriately assumed. To have precise estimates of treatment contrasts it is necessary to eliminate these trend effects. Presence of trend effects caused by variation due to moderate slopes may be handled through the analysis of covariance, treating trend values as covariates or using trend free block designs.

Some experiments may be planned to study the effect of soil erosion on the productivity. In such experiments, the soil erosion is done artificially at different levels in different experimental plots and their effect is seen on the yield. Artificial creation of soil erosion is quite difficult to be made. Moreover, this also amounts to destroying some of the upper layers of the soil from a part of the land. Therefore, it is always better to plan such experiments in minimum possible number of experimental units because of the scarcity of the natural resources. Minimally connected designs are very useful in such experimental situations. To ensure that all pairwise comparisons of treatments are possible in a block design, the minimum number of experimental units required is equal to one less than the sum of the number of blocks and treatments. A design in minimal number of experimental units that provides all possible treatment comparisons is called a minimally connected design. These designs are also very useful for experiments related to animal sciences because the experimental unit, the animals, is scarce. However, in minimally connected designs, no degree of freedom is left for estimation of experimental error. Therefore, efficient minimally connected designs with some extra observations need to be identified/developed so as to enable the experimenter to estimate the experimental error.

In large number of experiments, a fixed quantity of inputs, may be same dose of fertilizer, same dose of insecticide or pesticide, etc. are applied. The fixed quantity of the inputs applied are either (i) a combination of two or more ingredients whose total is a fixed quantity, i.e., their levels are not independent or (ii) quantity of inputs applied at different experimental stages such that sum total of the quantities applied at different experimental stages is fixed. Such experiments are conducted using a randomized complete block (RCB) design. The data is analyzed as per procedure of design adopted. This analysis only identifies promising treatments among the treatments tried in the experiment. Experimenter is also interested in obtaining a functional relationship between the proportions of inputs applied and the response so as to interpolate the responses at points that have not been tried in the experiment. experimenter is also interested in obtaining a functional relationship between the proportions of inputs applied and the response so as to interpolate the responses at points that have not been tried in the experiment and to obtain the optimum proportion of the inputs. These questions can be answered by drawing an analogy between such experiments and mixture experiments. The response is assumed to depend only on the relative proportions of the ingredients or components present in the mixture and not on the amount of the mixture. A functional relationship between the proportions of the inputs applied and the response can be obtained using experiments with mixtures methodology. The above relates to the discussion on how to analyze the data from the experiments conducted with fixed quantity of inputs applied at different crop growth stages. It has been observed that the design points for such experiments are chosen arbitrarily. Therefore, choice of proportions/ design points for experimentation is another issue. For this, designing experiments with mixtures is a very important and useful problem. A lot of literature is available on obtaining designs for experiments with mixtures. Therefore, before selecting the proportions for experimentation, a better coordination between experimenter and the statistician is desirable so as to get a set of different proportions that are chosen according to well defined statistical criteria. Most of the literature, however, on the designs for experiments with mixtures is based on the situations where the proportions on same input are taken. The experimenter may, however, be interested in studying the behaviour of split application of fertilizer and irrigation (supplied through watershed). Obtaining efficient designs for such experimental situations is still an open problem.

It is clear from the above discussion that many efficient designs, sophisticated analytical procedures and the software packages for carrying out statistical analysis of data are available in literature. Designs adopted for experimentation under National Agricultural Research System is, however, still preliminary in nature and analytical tools employed also of elementary level. To disseminate the development in the field of designed experimenters to the experimenters and practising statisticians, IASRI has taken a lead in generating "WEB DESIGN." All the designs for various experimental situations would be available for experimenters. A discussion forum is also being created so as to introduce E-advisory services.

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4. Small Area Statistics for Agro-climatic Regional Planning

B.V.S. Sisodia

Agro-Climatic Region Planning approach suggested by Alagh (1998) and initiated by Planning Commission, New Delhi is a button up Planning process which revolves around sub-regionalization of districts based on resource endowment, climatic factors, rainfall, ecological parameters etc. This necessitated requirement of small area statistics for better planning of development projects in agriculture/non-agriculture sector in order to increase the level of income of the people of the region and thereby improve the livelihood of the households.

In the present paper, some methodological issues for delineating small areas, i.e. sub-regions within blocks or districts through agro-climatic characterization by using computer based tools like Geopraphical information system/Remote Sensing techniques are discussed, particularly for agro-climatic regional planning of hill regions. A brief review of estimation techniques for small area statistics is also presented in the paper. Finally, some suitable estimation strategies for estimating small area statistics, particularly, in context of agro-climatic regional planning with special reference to hilly areas are suggested. Some important suggested estimation strategies are synthetic and composite estimators, some model-dependent techniques and strategies based on simulation techniques.

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5. Statistical Considerations in Agricultural Research under Rainfed Conditions

N.S. Gandhi Prasad

Agriculture under rainfed conditions is a matter of serious concern to the many. The farmers' expectations are always under uncertainty owing to recurring vagaries of weather, erratic incidence of diseases and pests, ever increasing costs of inputs, non-remunerative prices. The attempts to increase the productivities through seed have been successful to a marginal extent under rainfed conditions. It has been universally accepted that there is a wide gap between actual and attainable crop water productivity especially in rainfed environments. The central issue of rainfed farming is not necessarily a package of technologies, but building up the capacity of farmers to support a decent livelihood through encashment in their economic conditions. The mismatch between promise of available technologies and its actual performance may be explained by a number of factors like risk persistence, inadequate communication, inappropriate technologies, poor credit facilities and host of many other factors. Risk management is therefore central to achieve the goal of sustainable rainfed agriculture.

Risk management is central to land management leading to sustainable rainfed agricultural development. Risk in agriculture is fundamentally related to water scarcity and therefore all strategies leading to sustainable development must be based upon the potential to build water resources and management.

It is hypothesized that breakthroughs in molecular breeding and advances in modeling, information and communication technologies will accelerate our understanding of the above inter related factors and identification of interventions will lead to improve crop productivity at various scale levels. Any research in the area of rainfed agriculture must be aimed to increase the crop water productivity without increasing the water. Any research in this direction must be aimed with the following broad objectives:

1. Enhancing the productivity per unit of water utilized.
2. Reducing the outflows from the domain of the interest.
3. Enhancing the effective use of rainfall, water stored in the domain of the interest and water with marginal quality.

Keeping in view the above, in the present talk, some considerations in planning and analyzing the experiments conducted in rainfed environments will be discussed. Main emphasis will be laid on

(i) Statistical issues related to importance, characterization and selection of rainfed environments

(ii) Climate impact assessment

(iii) Systems approach to land use planning

(iv) Crop diversification

(v) Watershed in the approach to rainfed areas

(vi) Lack of uniformity in experimental data and

(vii) Incidence of large amount of variability in the experimental data pertaining to rainfed conditions.

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6. Methodological Issues Related to Rainfed Agriculture

Girish Kumar Jha

Indian agriculture is predominantly rainfed. Out of the 143 hectare of total cultivated area in the country, nearly 70 percent area is rainfed and face moisture stress at one time or the other. The rainfed area of the country contributes to about 42 percent of the total food grain production. In this talk, an attempt has been made to highlight some of the issues relating to sampling methodology and statistical forecast modeling relevant for rainfed agriculture.

The sampling methodology for usual crop-cutting experiments primarily developed for irrigated agriculture cannot be used as such due to the peculiar nature of rainfed agriculture. Hence, there is a need to modify the existing sampling methodology for accurately assessing the area and production of crops grown in these areas.

Further, the information on the number of wet and dry days and the expected length of wet and dry runs and their frequencies at different points of time is very useful for the purpose of crop planning as well as in optimizing various crop operations. Therefore, apart from traditional forecasting techniques, the role of soft computing tools like artificial neural networks, fuzzy regressions etc. for prediction of wet and dry days have also been discussed.

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