Dr. G. R. Sandhu

SUSTAINABLE AGRICULTURE

P N C S

A Pakistan National Conservation Strategy Sector Paper

2

SUSTAINABLE AGRICULTURE

Dr. G. R. Sandhu

ENVIRONMENT &
URBAN AFFAIRS
DIVISION,
GOVERNMENT
OF PAKISTAN

IUCN
The World Conservation Union

ACKNOWLEDGMENTS

Many thanks to Dr. Amir Muhammed and Asianics Agro-Dev International
for their assistance in the technical editing of this paper

The Pakistan National Conservation Strategy was prepared by the Government
of Pakistan (Environment and Urban Affairs Division)
in collaboration with IUCN – The World Conservation Union

It was supported by the Canadian International Development Agency

Additional sector activities were supported by
the United Nations Development Programme

IUCN – The World Conservation Union, Pakistan
1 Bath Island Road, Karachi 75530

Editors: Tehmina Ahmed & Yasmin Qureshi
Editorial Advisors: Dhunmai Cowasjee & Saneeya Hussain

ISBN 969-8141-05-7

Design: Creative Unit (Pvt) Ltd
Formatting: Umer Gul Afridi, Journalists' Resource Centre for the Environment
Printed in Pakistan by Rosette

CONTENTS

Figures

PREFACE

This monograph is one of the 29 sectoral and programme papers produced to support the preparation of the Pakistan National Conservation Strategy. The NCS is a comprehensive review of the state of the country's environment, and of government and corporate policies, the voluntary sector, community and individual practices, which support or hinder sustainable development. The objective of the NCS is to identify strategic initiatives to conserve the country's natural resources which are the base for lasting improvements in the quality of life.

Environmental impacts do not respect sectoral or administrative boundaries. Yet, conventional development planning is frequently focused on narrow performance criteria and associated financial requirements, ignoring huge costs on downstream ecosystems and economic activities dependent on them. These costs cannot be avoided and must be paid by society, the only questions are when and by which group.

To facilitate an understanding of such 'externalities', one of the first steps of the National Conservation Strategy was to undertake assessments of cross-sectoral impacts from the point of view of each major activity sector. In order to facilitate comparison, the reports were prepared according to common terms of reference. Subsequently, major programme areas that must be given priority in the transition to a sustainable society were identified. The list of economic, environment and programme areas is given overleaf.

A paper on each sector was produced by a well recognized expert supported by peer reviewers in related specialities. The key insights have been incorporated into the Strategy. Since the papers are the reference base of the strategy and contain special interest material, a decision was taken to publish them serially in the form of monographs. It is hoped they will be found useful by researchers of sustainable development in various facets of national life as well as by the interested lay reader.

The sectors are:

1. Economic sectors:

- Agriculture, forestry, livestock, fisheries.

- Mining, energy, industries, transport.
- Human settlements and recreation.

2. Environmental impact sectors:

- Soil degradation, loss of biodiversity, and over harvesting of renewable resources.
- Municipal and industrial discharges, environmental health effects, and misuse of water resources.
- Destruction of cultural heritage.

3. Programme areas:

- Incorporation of environment in education, communication, and research; enforcement of laws and regulations; improved administration; use of economic instruments to align market forces with sustainability; promotion of conservation ethics.
- Programmes to promote population planning, women in development, and regional equity.
- Creation of grassroots institutions, with participative management.

SUSTAINABLE AGRICULTURE

1. THE AGRICULTURAL SCENARIO

Agriculture is the single largest sector of Pakistan's economy having contributed 26% to the gross domestic product (GDP) during 1988-89. It employs 51% of the total labour force and supports, directly or indirectly, 70% of the country's population. Agriculture's share in export earnings amounts to about 75%; this includes both raw and processed agricultural commodities. Although the contribution of agriculture to GDP has shrunk over the years, due to structural changes in the country and to a relatively faster growth in the industrial sector, agriculture itself has maintained a steady expansion rate of 4% per annum since the early 1960s. Besides meeting the food needs of the country's population, major industries like cotton, textiles and sugar, along with many medium- and small-scale industries, are dependent on agriculture for raw materials. Thus, the economic welfare of the majority of the people is critically dependent on agricultural resources.

The total population of Pakistan, as estimated on 1 January 1990, is 110.36 million people, of which approximately 70.4% are rural based. Out of the country's total geographic area of 79.61 million hectares, only about 20.92 million hectares are cultivated (see Table 1). Thus, while the available per person area is 0.8 hectare, the food, feed, fiber and fuel requirements have to be met from as small an area as 0.2 hectare per person.

The major crops grown are wheat, rice, cotton, sugar cane and maize. Gram and other pulses, oil-seeds and fodder crops are also grown in different parts of the country on sizeable areas. As Table 2 shows, in Pakistan the average yields of crops are low as compared with other countries.

These low yields are largely due to the failure to adopt improved production practices. In certain situations the appropriate technology may not be available, but in most cases improved production methods are known and their potential has been demonstrated at experiment stations and with many progressive farmers. Table 3 highlights the gap that exists between the potential and realized yield for some major crops.

A number of macro- and micro-level policy issues and socio-economic constraints have prevented the full use of this known production potential.

TABLE 1

POPULATION AND LAND USE PATTERN

	(million)		(per cent)	
Population (as estimated on 1.1.90)				
Total	110.36		100.00	
Urban	32.66		29.60	
Rural	77.70		70.40	
Total labour force	31.82	(100.00%)		
Agricultural labour force	16.28	(51.15%)		
Land use	(million hectares)		(per cent)	
Geographic area	79.61		100.00	
Reported area	57.78		72.00	(100.0%)
Cultivated area	20.92		—	(36.2%)
Culturable waste	10.33		—	(17.9%)
Forest area	2.92		3.80	(5.1%)
Not available for cultivation	23.61		—	(40.8%)

Source: Economic Adviser's Wing, Finance Division. N.d. *Economic Survey 1989-90.* Islamabad: Government of Pakistan.

TABLE 2

AVERAGE YIELDS OF MAJOR CROPS, 1987-88

COUNTRY	WHEAT	RICE	MAIZE	COTTON	SUGAR CANE
			(kilograms per hectare)		
USA	2,531	6,143	7,494	2,080	79,520
India	1,998	1,999	1,226	507	59,732
Canada	1,950	—	7,022	—	—
Turkey	2,011	—	4,211	2,382	—
Mexico	4,231	—	1,310	3,173	—
France	5,560	—	—	—	—
Japan	—	6,186	—	—	—
Egypt	—	5,714	—	2,376	79,472
Pakistan	1,865	2,477	1,391	1,716	39,227

Source: Ministry of Food and Agriculture. N.d. *Agricultural Statistics of Pakistan 1988-89.* Islamabad: Government of Pakistan.

TABLE 3

YIELD GAP OF VARIOUS CROPS IN PAKISTAN, 1982-83

COMMODITY	POTENTIAL YIELD	AVERAGE YIELD	YIELD GAP	UNACHIEVED POTENTIAL
		(kilograms per hectare)		(per cent)
Wheat	6,425	1,695	4,730	74
Paddy	9,489	1,703	7,786	82
Maize	6,944	1,272	5,672	82
Sugar cane	256,000	35,672	220,328	86
Rape & Mustard	2,743	641	2,102	77
Potato	38,128	10,403	27,725	73

Source: Muhammed, A. 1984. *Approaches to the Transfer of Crop Production Technology in Developing Countries.* Consultancy Report for U.N. Development Programme and U.N. Food and Agriculture Organisation.

2. MAJOR RESOURCES FOR AGRICULTURE

Land and water are the two major natural resources for agricultural production. Their development, use and distribution have played a major role in the process of agricultural development in Pakistan. A critical look at the pattern and extent of their use will give an idea of the achievable production potential, if these resources are used more judiciously and various other constraints to production are removed.

TABLE 4

ORGANIC CONTENT OF SOILS IN THE PUNJAB

SAMPLES*	CATEGORIES	RANGE
77.5%	Poor	0.0-0.8%
18.5%	Medium	0.8-1.2%
4.0%	Adequate	>1.2%

Source: Soil Fertility Survey and Soil Testing Institute, Lahore.

* A total of 337,714 samples were analysed.

LAND

As already mentioned, out of the total reported area of 79.61 million hectares in the country, 20.92 million hectares are cultivated, while the rest are culturable waste (10.33 million hectares), forest (2.92 million hectares), and area not available for cultivation (23.61 million hectares). Since this paper is confined to agriculture, further discussion on land will focus primarily on the cultivated area. According to the Soil Survey of Pakistan, soils in Pakistan fall into more than 400 different soil categories. They are generally silty, calcareous and low in organic matter. As an example, the organic content of soils of the Punjab is given in Table 4.

The cation exchange capacity of these soils ranges from 8-16 milliequivalent per 100 grams soil. The soil structure is poorly developed. Mica, illite, and kaolinite are the dominant mineral phases in clay size fractions with traces of smectite. Soils are predominantly deficient in nitrogen and most crops respond to the application of phosphorus fertilizers also. There are small areas with soils deficient in potassium and zinc, especially in the rice growing regions.

According to the land capability classification done by the Soil Survey of Pakistan, the Canal

Command Area (CCA) covering 14 million hectares of land, has mostly fertile soils and a climate favourable to year-round cropping. Of the total CCA, 30.7% (4.1 million hectares) is Class I or very good agricultural land with no soil problems, highly suitable for intensive irrigated agriculture.

Another 42.9% (5.82 million hectares) is Class II or good agricultural land with minor soil limitations, but still well suited to common crops like rice and wheat. Of Class II land, 4.07 million hectares is clayey, about 0.8 million hectares is affected by patchy salinity/sodicity, while 0.63 million hectares is somewhat sandy or moderately shallow oversandy strata, with low water-holding capacity and rapid permeability. About 0.26 million hectares of Class II land is improperly drained due to a constantly wet surface, and/or a high water-table while another 0.06 million hectares has a gently sloping or uneven surface (29).

The severity of these problems is moderate in Class III land which occupies 5.7% or 0.78 million hectares of the CCA. Crop yields are low but can be profitably increased by improved management. Class IV land, covering about 0.48 million hectares or 3.5% of the CCA, have so many limitations that cultivation is not economical. This is marginal agricultural land with severe waterlogging, salinity, and sodicity problems. The improvement of this land to a high level of productivity would not be economical.

The uncultivated part of the CCA measuring 2.3 million hectares, consists mostly of saline/sodic soils in the upper, and strongly saline gypsiferous soils in the lower Indus plains. A small portion consists of very sandy soils, severely eroded soils and marshlands. About 70% of uncultivated salt-affected soils are economically reclaimable, given sufficient irrigation water and drainage. The remaining saline, sandy and eroded soils are not cultivable (29).

Out of the total cultivated area of 20.92 million hectares, the irrigated area measures over 15.68 million hectares. This is mainly confined to the Indus plains for which the river Indus and its tributaries are the main sources of irrigation.

TABLE 5

AREA IRRIGATED BY DIFFERENT SOURCES, 1988-89

SOURCE	AREA (million hectares)
Canals	11.23
Tubewells	3.97
Others	0.48
Total	**15.68**

Source: *Economic Survey 1989-90.*

A significant portion of cultivated land is also irrigated by private and public sector tubewells. The area covered through various sources of irrigation is given in Table 5. As evident canals cover about 72% of the total irrigated area in the country. Public and private sector tubewells irrigate another 25% while the remaining 3% is covered by minor sources of irrigation such as wells, tanks, *karezes* (underground tanks), etc.

WATER

Water is the second most important natural resource on which the agricultural productivity of the country is dependent. As already mentioned, Pakistan's agriculture is predominantly irrigated. Irrigation has been practised in various forms since time immemorial. The remains of Moenjodaro and Harappa, dating from 4000-3000 BC, show that the inhabitants of these once prosperous places were well-versed in 'well' and 'river' irrigation. Old inundation canals had existed along the rivers in the regions of Muzaffargarh, Dera Ghazi Khan, Shahpur, Khairpur, Peshawar Valley and numerous other places. These systems were dependent on high river levels during the flood season and covered only narrow stretches of land along streams throughout the Indus plains. These old irrigation systems were gradually transformed, partly during the pre-Independence British era, and partly during the post-Independence years, into a weir-controlled perennial canal system. Developed over a period of one and a half centuries, this perennial canal system is now considered the world's largest irrigation network.

After the signing of the Indus Waters Treaty in 1960, the major sources of water for canals in Pakistan have been the three western rivers, Chenab, Jhelum and Indus. The present irrigation network consists of three storage reservoirs at Tarbela, Mangla and Chashma, 16 barrages, 12 inter-river link and 43 main canals, and two syphons. Tarbela, Mangla and Chashma, with a storage capacity of 18.6 billion cubic metres, were built under the Indus Waters Treaty, to regulate seasonal river flow and to conserve water for irrigation during winter, when river inflow falls to only 19% of that in summer. The canals have an aggregate length of about 63,000 kilometres and deliver irrigation water to 11.23 million hectares through more than 89,000 watercourses. Currently, the total withdrawal of water at the canal headworks averages 103.5 million acre-feet (MAF), which represents an overall increase of 62% since 1947.

In addition to the grand canal system there are 272,962 private and 15,491 public sector tubewells. These pump out about 42 MAF of water and irrigate 3.97 million hectares of land besides supplementing some canal-fed areas. Continuous development of surface and underground water resources for irrigation has led to an increase in the irrigated area (see Table 6), and a consequent increase in productivity through larger cropped areas, higher cropping intensities, and better yields.

Although more irrigaton water has increased the extent of agricultural lands, the increase in supply combined with a lack of proper drainage has resulted in extensive waterlogging. Water use efficiency has been a major problem of the irrigation system. Conveyance and application losses of upto 60% directly affect crop yields and increase the problem of waterlogging and salinity.

Constraints to Irrigated Agriculture

Salinity and Waterlogging

Irrigated agriculture is threatened by waterlogging and salinity. Out of 15.68 million hectares of land under irrigation, 9.6 million hectares is arid, 3.8 million hectares is semi-arid and the remaining area lies in the sub-humid and transitional climatic zones (12). Intensive and continuous use of surface irrigation has altered the hydrological balance of the Indus Basin by substantially raising the water-table. It has risen to within 6 feet of the surface in over 25% of the Basin, and to within 10 feet in over one-third of the entire Indus plains. More than 40,000 hectares of irrigated land are lost to agricultural production each year, through waterlogging and salinity (12). Estimates of salt affected areas differ widely, because of the different

TABLE 6

INCREASE IN AREA IRRIGATED BY DIFFERENT SOURCES

YEAR	CANALS	TUBEWELLS	OTHERS	TOTAL
		(million hectares)		
1950-51	7.53	—	1.72	9.25
1960-61	8.59	0.25	1.57	10.41
1970-71	6.69	2.25	1.65	10.59
1980-81	11.46	2.81	1.00	15.27
1988-89	11.23	3.97	0.48	15.68

Source: *Economic Survey 1989-90.*

classification criteria used by various agencies. However, the latest estimate of 5.7 million hectares by the Soil Survey of Pakistan is considered the most authentic. Of this 2.4 million hectares are highly saline soils containing gypsum, 1.4 million hectares porous saline/sodic soils, and 0.6 million hectares dense saline/alkali soils (32).

Size of Land Holdings

Small farms are another major constraint to increased agricultural productivity, as such landowners do not have enough resources to invest in improved production methods. Because of the law of inheritance, holdings are subdivided and continue to become smaller. Table 7 shows that 75% of farms have less than 5 hectares of land, but constitute only 35% of the total area. Similarly only 9% of farms with areas of 10 hectares and above, control over 40% of the cultivated area. During the intercensual period between 1972 and 1980, the number of small farms of less than 2 hectares increased from 28% in 1972 to 34% in 1980.

Dryland Agriculture

About 80% of the total land mass of Pakistan or 25.7% of the cultivated area is rain-fed. Of the cultivated area, 15% in the Punjab excluding Cholistan, 44% in Sindh, 60% in Balochistan and a similar percentage in the North West Frontier Province (NWFP), are totally dependent on rain for their crop and livestock production.

Pakistan has a continental climate. Precipitation varies widely, from less than 125 millimetres to over 1,500 millimetres per annum. Monsoon precipitation dominates in some areas, while in other parts a winter precipitation pattern prevails. Average temperatures vary considerably: during the warmest parts of the year — May and June — daily maxima generally exceed 38°C, while in the south and south-west the maxima occasionally rises above 49°C. In the winter months, the minimum temperatures in some places, even in the plains, are several degrees below the freezing point. The climate of the rain-fed region is, however, suited to the production of many kinds of cereals, millets, legumes,

TABLE 7

PRIVATE FARMS BY SIZE, 1980

FARM SIZE	NUMBER		AREA	
(hectares)	(million)	(per cent)	(million hectares)	(per cent)
Under 0.5	0.33	8	0.10	*
0.5 to under 1	0.37	9	0.28	1
1 to under 2	0.69	17	0.97	5
2 to under 3	0.68	17	1.63	9
3 to under 5	0.92	23	3.57	19
5 to under 10	0.71	17	4.70	25
10 to under 20	0.26	6	3.39	18
20 to under 40	0.10	3	2.80	15
60 and above	0.01	*	1.62	8
All farms	**4.07**	**100**	**19.06**	**100**

Source: Ministry of Food and Agriculture. N.d. *Agricultural Statistics of Pakistan, Volume 1, 1986.* Islamabad: Government of Pakistan.

* Negligible

grasses, range forage and forests, although in areas of low rainfall, crops usually come under severe moisture stress and productivity is considerably reduced. In areas of optimum rainfall, vegetables and deciduous fruits are grown successfully, in addition to normal field crops.

The Green Revolution of the 1960s did not benefit the rain-fed areas as these were considered high-risk agricultural lands. However, these areas are too important a resource to be ignored. Rain-fed areas contribute 12.5% to national wheat production, which is greater than the total irrigated and rain-fed wheat jointly produced by the NWFP and Balochistan, or equivalent to 74% and 17% respectively of the total wheat production of Sindh and the Punjab. In addition, of Pakistan's overall production 69% jowar, 31% millet, 53% groundnut, 17% sesame, 23% rape and mustard, 17% sunhemp and a significant quantity of guar-seed are grown in these croplands (15).

Furthermore, nearly 40% of the livestock population in the Punjab is supported by the Punjab *barani* (rain-fed) tract. In Balochistan more than 80% of the livestock population is sustained by arid lands, and this means nearly one-fourth of the country's sheep and goat population. Similarly, a significant percentage of the livestock population of the NWFP and Sindh is supported by the arid and semi-arid regions of these provinces. Seventy per cent of the country's farm power still comes from the draft bullock, and the dryland areas are well known as breeding tracts of Dhajal, Rojhan, Dhanni, Bhag Nari and Thari draft cattle. These cattle are reared with great care and sold at attractive prices. With progressive mechanization of farm operations the demand for bullocks is decreasing, adversely affecting this trade. However, draft cattle can be substituted by dual purpose beef cattle, which can lead to increased milk and beef production.

The economy of the dryland areas is dependent mainly on crop and livestock production. Wheat, gram, barley, lentils, rape and mustard are mostly grown in winter, while jowar, millet, maize, pulses, guar, groundnut and sesame are commonly grown summer crops. About 60% of the total area is sown with winter crops, while 40% is planted during summer.

In most cases a single winter or summer crop is planted, but where rainfall patterns permit, a winter crop may be followed by a summer crop. Wheat continues to be the single largest dryland crop, with land left fallow during a rotation cycle. Cropping intensity in the Punjab, where farmyard and other organic manures are available, may reach 100%. However, in many areas the cropping intensity is much lower such as in the Balochistan highlands where dryland wheat is followed by four to five years of the land being left fallow (18).

Crop management practices in most areas are traditional, and usually lead to nutritional exhaustion of the soil. The indigenous plough does not permit tillage deeper than 7.5-10 centimetres. Repeated tillage over longer periods and in some areas chemical reactions in the soil, have led to the development of a hard pan at depths varying from 10-17.5 centimetres in different soils. This hard pan impedes rainwater percolation, hinders penetration by developing roots and is conducive to accelerated run-off, adversely affecting the moisture regime in the soils and ultimately plant growth. Again, water erosion in high rainfall areas and wind erosion in low rainfall areas affect the productivity of barani lands.

Although livestock production is a major industry of dryland areas, it suffers from mismanagement, malnutrition, disease and pestilence. A number of good local sheep breeds exist, but they all produce coarse wool. Foodgrains are given preference over fodder in the cropping system. Dry stalks of coarse grain crops, wheat, chaff and food legumes left over after grain separation, winter weeds, and rapeseed provide supplemental feed. In some areas, where soils are generally rich in nutrition, even wheat and barley are once grazed before they are allowed to mature (18). Rangelands which dominate the dry regions are mostly overgrazed. To enhance productivity, better water management and vegetation cover, among other things, should be given attention.

SOIL FERTILITY AND FERTILIZERS

Sixteen essential nutrient elements have been identified for the optimum growth of almost all plants. Some of these such as nitrogen, phosphorus, potassium, sulphur, calcium and magnesium are taken up by plants in relatively large quantities and are called macronutrients. Others are needed only in small amounts: termed micronutrients, the more important include zinc, copper, iron, manganese, boron, molybdenum and chlorine. For optimum plant growth, both macro and micronutrients are needed in a balanced quantity.

With an increase in cropping intensity and introduction of high yield crop varieties, soils have become deficient in many nutrients which are essential for plant growth. In the early 1950s a need for the use of nitrogen fertilizers was felt. About 1,000 nutrient tonnes of nitrogen was, therefore, imported. Since then, fertilizer consumption has been increasing. It particularly accelerated in the late 1960s when high yielding wheat and rice varieties were introduced. This was followed by the introduction of phosphorus fertilizer and, later on, potassium and micronutrients started being used. Nitrogen fertilizers have been used increasingly in comparison with phosphorus and potash fertilizers. Total fertilizer consumption reached 1,784 thousand nutrient tonnes in 1986-87 and then dropped slightly in the next two years (see Table 8).

The overall growth rate of fertilizer consumption was highest (31.8% compound growth) during 1965-70 (29). This was the during the Green Revolution when dwarf varieties of wheat and rice were introduced in the country. Afterwards, the growth rate declined and during 1980-87 it was estimated at 8.8%. During the Sixth Five-Year Plan period the annual growth in fertilizer consumption has been estimated at 7.1% against a target of 8%.

Before 1957, the fertilizer needs of the country were met from imports after which domestic production of nitrogen and then phosphorus fertilizers started. Now there are ten factories (seven in the public and three in the private sector) which produced 1,110 thousand nutrient tonnes of nitrogen and 106 thousand nutrient tonnes of phosphorus fertilizer during 1988-89.

TABLE 8

ANNUAL FERTILIZER OFF-TAKE IN PAKISTAN

YEAR	NITROGEN	PHOSPHORUS	POTASSIUM	TOTAL
		(thousand nutrient tonnes)		
1955-56	6.6	—	—	6.6
1960-61	31.4	0.4	—	31.8
1965-66	69.8	1.2	—	71.1
1970-71	251.5	30.5	1.2	283.2
1975-76	445.3	102.5	2.8	550.6
1980-81	842.0	226.9	9.6	1,044.3
1985-86	1,128.4	350.8	33.3	1,511.8
1986-87	1,332.4	408.9	42.6	1,783.9
1987-88	1,281.7	393.4	45.1	1,720.2
1988-89	1,324.9	390.4	24.5	1,739.8

Source: *Agricultural Statistics of Pakistan, 1988-89.*

TABLE 9

AREA UNDER FORESTS AND RANGELANDS

CATEGORY	NWFP	PUNJAB	SINDH	BALOCHISTAN	TOTAL
			(thousand hectares)		
Coniferous	1,105	25	—	131	1,261
Irrigated plantation	—	136	82	—	218
Riverine	—	54	241	5	300
Scrub	115	302	10	142	569
Coastal	—	—	345	—	345
Mazri lands	24	—	—	—	24
Linear plantation	159	—	—	—	159
Rangelands	150	2,723	489	787	4,149
Total	**1,553**	**3,240**	**1,167**	**1,065**	**7,025**

Source: *Agricultural Statistics of Pakistan, 1988-89.*

In addition to domestic production, 200 thousand nutrient tonnes of nitrogen, 264 nutrient tonnes of phosphorus and 57 nutrient tonnes of potash fertilizers were imported during the same year to meet the total fertilizer demand. The use rate comes to about 64, 20 and 2 kilograms per hectare for nitrogen, phosphorus and potash respectively. The ratio between the use of nitrogen and phosphorus is 3.3:1. The use of potash is nominal.

Fertilizer has been subsidized to encourage its use. The subsidy was, however, withdrawn from nitrogen fertilizers in 1986.

Soil Fertility and Soil Testing Institutes work in all provinces providing advisory services to farmers on nominal charges. A National Fertilizer Development Centre operates in the Ministry of Planning and Development and studies fertilizer problems and provides policy guidelines.

FORESTS AND RANGELANDS

Forests

Pakistan is a forest-poor country, with only 2.92 million hectares or 3.8% of its land mass covered with natural forests. The primary reason for the lack of this resource is the arid or semi-arid climate of almost 80% of the country's land area, where precipitation is too low to support tree growth. The total area under different types of forests and rangelands in the country, is given in Table 9. This includes natural forests and irrigated plantations.

Forests in Pakistan produce both softwood and hardwood timber. Of the total production, coniferous timber constitutes slightly more than half. Table 10 gives the quantity of timber and firewood produced in the country, including Azad Jammu & Kashmir, by various sources (1).

The present consumption of wood in the country is low. It stands at 2.357 million cubic metres for timber and 19.70 million cubic metres for firewood. It is estimated that by the year 2000 this demand will rise to 3.36 million cubic metres and 30.66 million cubic metres respectively. Due to the shortage of indigenous wood resources, substitute materials are being increasingly used in many sectors of the economy. In addition, large quantities of wood and wood products are imported every year. The import bill for this is constantly rising, from

TABLE 10

SUPPLY SOURCE OF TIMBER AND FIREWOOD

SOURCE	TIMBER		FIREWOOD	
	(million cubic metres)	(per cent)	(million cubic metres)	(per cent)
State forests	0.482	18.2	2.21	10
Farmlands	0.922	34.8	19.94	90
Imports (wood & wood products)	1.243	47.0	—	—
Total	**2.647**	**100.0**	**22.15**	**100**

Source: Amjad, M., and N. Khan. 1990. *The State of Forestry in Pakistan (1989).* Peshawar: Pakistan Forest Institute

Rs. 2,389 million in 1986-87 to Rs. 3,256 million in 1988-89.

In order to narrow the gap between production and demand, steps have been taken to raise the productivity of existing forests, particularly coniferous forests in the north which, at present, are far below their optimum production level. Out of 2.98 million hectares of state-managed forests, only 1.27 million hectares have so far been covered under management plans. Existing management plans are based on low input and output variables. Hence better managed forest and species' yield estimates could not be made. The average annual per hectare yield for forest areas in Pakistan, as indicated in the Sixth Plan, is 0.21 cubic metres; this is in comparison to 1.65 cubic metres in the United Kingdom and 1.19 cubic metres in the United States.

Rangelands

About 65% of the total area of Pakistan consists of rangelands. These rangelands extend from alpine pastures in the north to arid and semi-arid areas in the south. About 9 million hectares of high potential range can be found in the north and north-western parts of Pakistan, while about 48 million hectares of arid and semi-arid rangelands are located in the Punjab, Sindh and Balochistan (17). The distribution of rangelands in various parts of the country is given in Table 11.

Rangelands are the major source of feed for about 90 million head of livestock in Pakistan, including buffaloes, cattle, goats and sheep, donkeys, mules, horses and camels. Due to heavy over-grazing, the carrying capacity of these rangelands have been reduced by 10-50% of their potential (17). During the last 10 years, the population of goats and sheep, the principal range animals, has doubled, and grazing pressure on rangelands has increased tremendously. As there is little chance of an increase in the area given to fodder crop cultivation, due to competition with cereal crops, this trend is likely to continue in the future. Other major constraints are a lack of attention given to proper range-livestock management, and lack of participation of stockmen in range management activities.

AGRICULTURAL RESEARCH AND EDUCATION

Pakistan inherited very few agricultural research institutes at the time of Independence. None of the central research institutes established by the Imperial Council of Agricultural Research were located in the territories that now constitute Pakistan. Considerable progress has been made in the past 40 years to establish a credible network of agricultural education and research institutions. For graduate and post-graduate agricultural education, Pakistan now has three Agricultural Universities — located at Faisalabad, Tandojam and Peshawar — a Barani College

TABLE 11

DISTRIBUTION OF RANGELANDS IN PAKISTAN

PROVINCE	TOTAL AREA	RANGELANDS	
		Area	Percentage of Total Area
	(million hectares)	(million hectares)	
Punjab	20.63	9.70	47
Sindh	14.09	9.28	65
NWFP	10.17	5.68	55
Balochistan	34.72	32.43	93
Northern Areas	7.04	3.50	50
Azad Jammu & Kashmir	1.33	0.60	45
Total	**87.97**	**61.19**	**65**

Source: Khan, C. M. A., and N. Mohammad. 1987. Rangelands in Pakistan.In *Proceedings of US-Pakistan Workshop on Arid Lands Development and Desertification Control, Islamabad, January, 9-15, 1986*, 13-22. Islamabad: Pakistan Agricultural Research Council.

in Rawalpindi, Agricultural Colleges in Multan and Quetta, a Faculty of Agriculture in the Gomal University at Dera Ismail Khan and a College of Veterinary Science in Lahore. These institutions all put together produce over 1,100 graduates and post-graduates in agriculture and veterinary sciences every year. There are 65 research institutes, and 163 research stations, centres and laboratories, dispersed over various agro-ecological regions of the country, that conduct research on different aspects of agriculture. Six Agricultural Training Institutes at Peshawar, Rawalpindi, Rahim Yar Khan, Sakrand, Sargodha, Quetta and Rawalakot cater to the training needs of middle-level technicians, both for public and private sector agricultural services.

The Pakistan Agricultural Research Council (PARC) was established in the mid-1970s through the reconstitution of the Food and Agriculture Council of Pakistan and assigned the primary role of co-ordinating agricultural research at the national level. In 1978 it became an autonomous body at the Federal level. PARC's technical staff now exceeds 600, of which over 100 have doctorate degrees and the remaining are master of philosophy or master's degree holders. There are a number of other federal institutes engaged in agricultural research.

At the provincial level 16 government agencies operate 141 research establishments. The Provincial Governments of the Punjab, Sindh, and the NWFP have established Agricultural Research Co-ordination Boards, to co-ordinate research within the provinces but these have not proven effective. There is a need to strengthen and streamline their operations.

AGRICULTURAL EXTENSION SERVICES

An efficient extension system is a must for effective transfer of technology to the farmers. All four provinces maintain fairly large extension service departments. In the federal territory of Islamabad, the responsibility for agricultural extension rests with the Islamabad Capital Territory Administration. The provincial extension departments are headed by the Director-Generals of Agricultural Extension.

In the past these departments were responsible for the supply of fertilizers and pesticides in addition to their mandate for technology transfer, but later their role changed considerably. Agricultural inputs are now distributed through autonomous agricultural supply corporations and several private agencies. The extension departments are engaged solely in the transfer of improved production methods evolved by the agricultural research system of the country. Demonstration trials, distribution of relevant literature, audio-visual presentations through radio and television, and farmer meetings are some of the methods used by these departments to achieve their objective. A Training and Visit system of agricultural extension is also operating under a World Bank project, in a majority of districts in all four provinces. The main emphasis of this project is the validation of technology, practical training of extension staff and regular visits of specialists to the farmers.

The extension services in the country have not been able to achieve their goals effectively because of a number of bottlenecks. These include weak research-extension linkages, lack of adequate resources for on-farm demonstrations, poor mobility, inadequate research and training in extension methodology and lack of an effective system of continuing education for extension personnel at various levels.

3. INTERACTION OF AGRICULTURE WITH OTHER SECTORS

AGRICULTURE AND ENVIRONMENT — A GLOBAL VIEW

No other human activity contributes more to a healthy human environment than agriculture. Cultivated crops and plants remove millions of tonnes of carbon dioxide from the air, and in turn, release corresponding quantities of oxygen into the atmosphere on a worldwide basis. Unfortunately this balance has been greatly disturbed in recent years, giving rise to serious problems of management of soil and water (14).

Economic growth and development obviously involve changes in the physical ecosystem. Settled agriculture, the diversion of river waters for irrigation, planting of commercial forests, and genetic manipulation of plant and animal species are all examples of human interventions in natural systems during the course of development. Until recently such interventions were small in scale and their impact was limited. Today these interventions are more drastic in scale, and consequently more threatening to life support systems (20). The world has become increasingly conscious of this degradation of the environment from human interventions, and the idea of sustainable development is receiving much greater attention.

Sustainable development has a number of aspects but as the scope of this paper is primarily agriculture, further discussions will be confined to the sustainability of agriculture only. The Technical Advisory Committee of the Consultative Group on International Agricultural Research has defined sustainability of agriculture as:

> "Sustainable agriculture involves the successful management of resources for agriculture to satisfy changing human needs while maintaining and enhancing the quality of the environment and conserving natural resources" (24).

The world produces more food per capita today, than ever before in human history. In 1988, it produced 540 kilograms per head of cereals and root crops, the primary sources of food. This unprecedented growth in food production has been achieved by:

- Using new crop varieties designed to maximize yields.
- Applying more chemical fertilizers.
- Using more pesticides.
- Increasing area under agriculture.

Many developing countries in Asia and Latin America have made good progress in food production since the mid-1960s. Several of the traditionally food deficit or food importing countries have now become self-sufficient and even food exporters. What is even more significant is that this increase in food production has come largely from increases in productivity per unit area. This is considered to be an important gain because many of the developing countries, particularly those of South and South-East Asia, are population-rich but land-poor. Today, the world grain stocks have increased to more than 450 million tonnes.

In spite of this abundance, more than 730 million people in the world do not eat enough to lead fully productive lives. There are places in the world where too little is grown and places where large numbers of people do not have the means to buy. And there are broad areas of the earth, in both industrial and developing nations, where the emphasis on increased food production is undermining the base for future production.

Scientists and planners all over the world are worried. For them, increasing food production to keep pace with unabated population growth is still an unfinished task. Although most countries of the world are in the process of demographic transition towards 1% population growth, the progress towards the final stage of this transition is lagging behind dangerously in Africa, the Indian subcontinent, Latin America, the Middle East, and South-East Asia (7). It is predicted that between 1980 and 2000, world population will increase by 1.7 billion and 90% of this growth will occur in developing countries. This tremendous increase in population will require at least 50-60% greater agricultural output than in 1980 (38).

It is quite evident now, that any increase in food production has to come primarily from an increase in the productivity of currently cultivated soils rather than bringing new land into farming. In fact, a large portion of currently tilled marginal areas will have to be phased out of agriculture for economic and ecological reasons. Land, thus, is a shrinking resource for agriculture, because some of it is being taken out of production all the time and diverted to uses such as roads, housing and industry.

At the same time, short-sighted policies are leading to degradation of the agricultural resource base in almost every continent. These include soil erosion in North America; soil acidification in Europe; deforestation and desertification in Asia, Africa and Latin America; and water pollution almost everywhere. Some of these effects arise from trends in energy use and industrial production, while others accrue from population pressure on limited resources. But agricultural policies emphasizing increased production without regard for environmental considerations have also contributed to this deterioration. Increases in cropped areas, in recent decades, have often extended cultivation to marginal lands which are prone to erosion.

Modern agricultural production technologies have raised the hope that hunger can be eliminated, and that the carrying capacity of the land increased through better use of soil, water and air. Nevertheless, the ecological sustainability and economic viability of new methods is increasingly at stake. The rising human and livestock populations, with their ever-expanding food and fodder needs, exert great pressure on the stabilizing elements of agro-ecosystems.

Erosion reduces the soil's ability to retain water, depletes it of nutrients and reduces the depth available for roots to take hold. It has been estimated that if soil erosion continues at the 1983 rate, loss in rain-fed cropland in the developing world would range from 9.7% to 35.6%, leading to an overall decrease of 28.9% in crop production (38). Table 12 gives the effect of soil erosion on the global agricultural resource and productivity base.

Poorly designed and implemented irrigation systems have caused waterlogging and salinization of soils. It is estimated that as much as half of the world's irrigation schemes suffer to a varying degree from these problems and, on a global level, some 10 million hectares of irrigated land is abandoned every year.

Excessive use of chemical fertilizers cause damage to water resources through run-off of nitrogen and phosphates. Similarly, increased use of chemicals for the control of insect pests, weeds, and fungi threatens human health and the lives of other species. According to an estimate 10,000 people in developing countries die

TABLE 12

EFFECTS OF SOIL EROSION ON PRODUCTIVITY

	AFRICA	SOUTH WEST ASIA	SOUTH EAST ASIA	SOUTH AMERICA	CENTRAL AMERICA	GLOBAL AVERAGE
Decrease in area of rain-fed cropland (30)	16.5	20.0	35.6	9.7	29.7	17.7%
Decrease in rain-fed crop productivity (per cent)	29.4	35.01	38.6	22.6	44.5	28.9

Source: Swaminathan, M. S. 1987. *Agro-Forestry in Asia. The Promise of Agro-Forestry for Ecological and Nutritional Security. The Potential of Agro-Forestry*, 19-41. Nairobi: International Council for Research in Agro-Forestry.

each year from pesticide poisoning, and another 400,000 suffer acutely from its effects.

Forests are crucial for maintaining and improving the productivity of agricultural land. Growing populations and decreasing availability of arable land, particularly in developing countries, have forced people to look for new land in the forests. Such a shift is leading to large-scale deforestation which is severely disrupting mountainous areas, upland watersheds and the ecosystems that depend on them. If the present trend of population growth persists, forests and pasture lands will be further reduced. The effect on the Himalayan mountains, which is a very delicate agro-ecosystem, is projected in Figure 1 (35).

Twenty-nine per cent of the earth's land area suffers from slight, moderate or severe desertification and an additional 6% is classified as extremely desertified. The process of desertification affects almost every region of the world, but it is most destructive in the drylands of South America, Asia and Africa. For these three continents combined, 18.5% or 870 million hectares of productive land are severely desertified. Land permanently degraded to desert-like conditions continue to increase at an annual rate of 6 million hectares. Each year, 21 million hectares of additional land becomes uneconomical for cultivation because of desertification.

Eternal vigilance is the price of stable agriculture. A rapidly growing population and its ever-expanding needs for food and fuelwood is threatening agricultural stability. Political and commercial greed, the genuine needs of the poor for fuel and fodder, inappropriate technologies, and the absence of a systems approach in the design and implementation of agricultural and industrial projects in ecologically fragile areas have all contributed to increased environmental deterioration. B.F Skinner, quoted by M.S. Swaminathan (38) has rightly emphasized

> "Every new source from which man has increased his power on earth has been used to diminish the prospects of his successor. All his progress is being made at the expense of damage to the environment, which he cannot repair and cannot foresee."

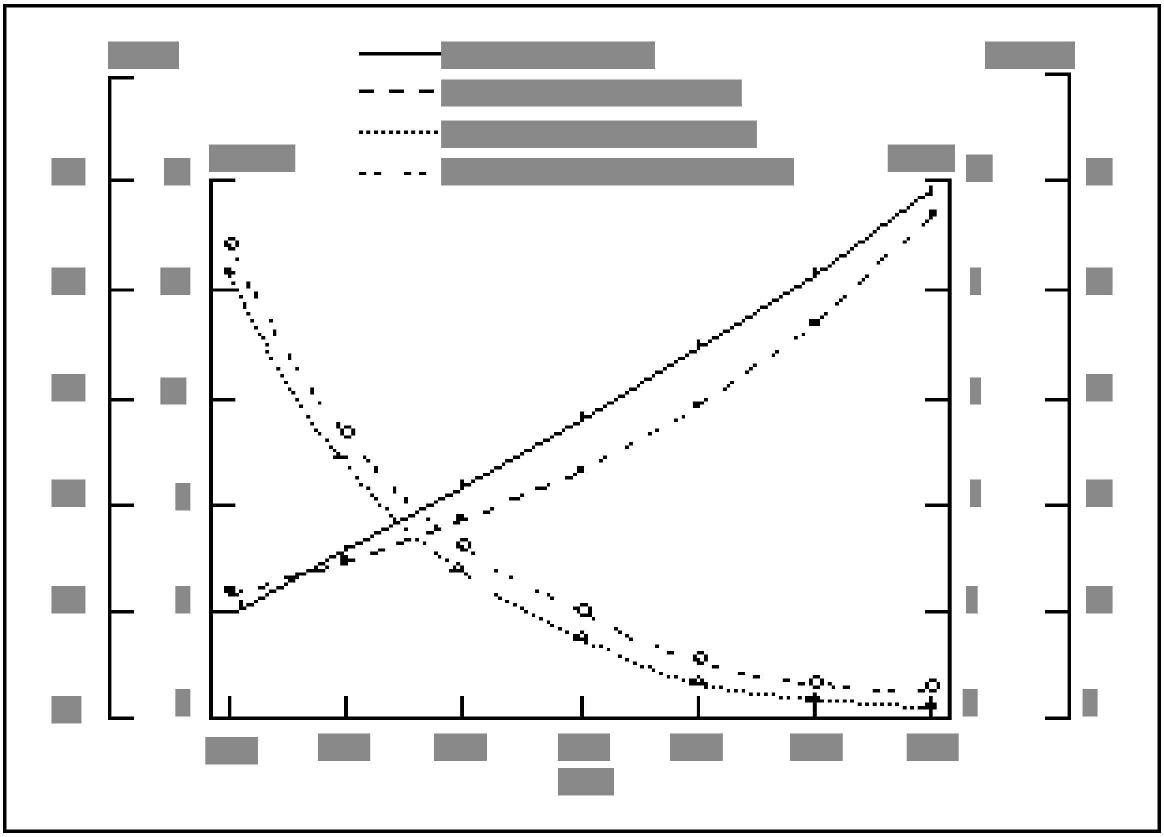
SPECIES AND ECOSYSTEMS

The conservation of living natural resources vis-a-vis plants, animals, micro-organisms and the non-living elements of the environment on which they depend is crucial for development. The germplasm of living species and the genetic variability that exists within each species contributes to agriculture, medicine and provides new raw material for industry.

There is a growing concern that species are

FIGURE 1

PROJECTED CHANGE IN POPULATION, CATTLE, FOREST AND GRASS STOCKS IN THE HIMALAYAS



Source: Shah, S.L. 1981. Ecological Degradation and Future of Agriculture in the Himalayas. *Indian Journal of Agricultural Economics* 37, no. 1: 19-26.

disappearing at a rate never before witnessed on this planet. Habitat alteration and species extinction are not the only threat, the planet is also getting impoverished by the loss of varieties within species. Numerous studies document this crisis with examples from tropical forests, temperate forests, mangrove forests, coral reefs, savannah, grasslands and arid zones. Species that are important to human welfare are not just the wild relatives of cultivated crops or domesticated animals. Species such as earthworms, bees, termites are also important in terms of the role they play in a balanced, healthy and productive ecosystem.

FERTILIZER USE AND ENVIRONMENTAL POLLUTION

To cope with the demand for increased agricultural production in Pakistan, the use of inorganic fertilizers is bound to increase in the future. Table 13 gives the projected fertilizer demand, local production and expected shortage to be met out of imports. It is clear from the

TABLE 13

PROJECTED FERTILIZER DEMAND, LOCAL PRODUCTION AND SHORTFALL

YEAR	DEMAND	LOCAL PRODUCTION	SHORTFALL
		(thousand nutrient tonnes)	
1987-88 (estimated)	1,750	1,213	537
1992-93 (end of 7th Five-Year Plan)	2,390	1,505	885
1995-96	2,600	1,505	1,095
2000-01	3,000-3,300	1,505	1,795

Source: National Fertilizer Development Centre, Planning and Development Division. 1988. *Report of the National Fertilizer Development Centre.* Islamabad: Government of Pakistan.

above data that Pakistan will have to produce increasingly larger quantities of fertilizers in the years to come to ensure a significant increase in crop yields. Pakistan's minimum requirement of fertilizer in the year 2000 would be nearly 3,300 thousand nutrient tonnes. This estimate has been worked out on the projected food requirements at the end of the century, and the expected yield increases in response to the application of fertilizer.

Nitrate Pollution

Concern with large-scale use of fertilizers in agriculture arises from the problem of chemical fertilizer pollution. Food is being contaminated by the improper use of fertilizers. Unless applied at an appropriate time, and according to the requirements of the crop, chemicals can accumulate in parts of the plant.

The fertilizer nitrogen has been a particular problem. In several developed countries, it has been observed that the nitrate concentration in lakes, rivers and groundwater can reach toxic levels. In this context it is important to remember that the greatest source of nitrogen in water is nitrates brought down by rainwater. On a worldwide basis, rainwater adds nearly 40 million tonnes of nitrogen to the soil every year. Biologically fixed nitrogen contributes another 175 million tonnes, while industrially produced nitrogen is estimated to be 60 million tonnes worldwide.

A recent study analysed 140 samples of twelve varieties of wheat and 80 samples of wheat flour from various regions of the Punjab. It was found that the nitrate content of the wheat flour ranged from 82.2-478.9 parts per million (ppm). Based on the fact that most of the caloric and protein requirements of people are met from cereals, about 104-239 milligrams of nitrate are being consumed daily by an adult; in comparison, there is a maximum limit of 10 ppm nitrate in drinking water.

Nitrogenous fertilizers such as urea, when applied to soil, are converted into ammonia by common heterotrophic bacteria (*Pseudomonas*, *Bacillus*, *Clostridium* and *Micrococcus*) and fungi. Ammonia can be taken up by certain crop plants like paddy or oxidized by a group of bacteria (*Nitrosomonas*, *Nitrococcus*, *Nitrospira*) to nitrite, which is oxidised to nitrate by *Nitrobacter*. Under normal conditions, nitrite does not accumulate in the soil, but if the activity of *Nitrobacter* ceases due to unfavourable conditions, nitrite could adversely effect crop production because it is toxic to plants and micro-organisms.

Nitrites are ten times more toxic than nitrates. They are formed through the reduction of nitrates, during the storage of cooked food and by microflora present in the mouth and gastro-intestinal tract of humans, particularly infants. Nitrites are reported to produce methaemoglobinaemia in infants and preschool children. These are also recognized as the precursors of nitrosamines and nitrosamides which are carcinogenic, mutagenic and teratogenic (34).

The future will see a marked increase in the application of nitrogen fertilizers and manures in different forms for higher productivity. Chemical fertilizers containing ammonium salts or urea are generally nitrified within three to seven days in the soil, whereas organics such as compost, farmyard manure and sludge are converted to nitrate very slowly. It is very rare to have more than one-third of the added chemical nitrogen recovered by crops, the rest of it being leached along with soil water. When this run-off enters lakes or domestic water supplies, it causes pollution, eutrophication and nitrate contamination in drinking water. Fertilizers leaching deeper into the land, form a 'soil pan', an impervious layer of soil which is injurious to crops. These problems are still in their early stages and are mostly localized, but the anticipated increase in inorganic fertilizer use has already alerted environmentalists to the problem nitrate pollution will present in the future.

Methaemoglobinaemia

Part of the interest in nitrates and hence nitrifying bacteria is because of the disease known as methaemoglobinaemia, associated with the consumption of nitrate-rich waters, vegetables and forage crops. This disease occurs when nitrate consumed with water, food, or feed is reduced in the gastro-intestinal tract to nitrite. This nitrite enters the bloodstream and reacts with haemoglobin giving rise to methaemoglobin, a change that impairs the oxygen carrying capacity of the blood. It can be serious in infants under the age of three months (leading to a condition known as blue baby) and also ruminants. To prevent such cases, the nitrate level in drinking water should not be more than 10 ppm. Some plant species namely spinach, lettuce, celery and beets among vegetables, and corn, sorghum, oats and Sudan grass among fodder crops accumulate more nitrates (13).

Denitrification

The attention given to nitrate pollution through heavy application of nitrogenous fertilizers and manures has encouraged scientists to assess denitrification rates to counteract this toxicity. These studies have shown that bacterial nitrification followed by denitrification is the most suitable method for effective nitrate control. Denitrification occurs in anaerobic conditions and an organic substrata is required as a carbon and energy source. Some of the bacteria reported to be involved in this process are *Thiobacillus denitrificans*, *Micrococcus denitrificans*, bacteria of the genus *Pseudomonas*, *Azospirillum*, *Achromobacter* and *Serratia*. Denitrification is a negative process as far as nitrogen availability to crop plants is concerned, but it is a blessing in disguise as this process can alleviate nitrate pollution in the environment. Micro-organisms are also capable of decomposing different types of pesticides. Some of these micro-organisms can use pesticides as their sole source of carbon and energy (13).

Alternatives to Fertilizers

In traditional farming systems, when farms were relatively larger and pressure on land was not as high, most of the nutritional requirements of the soil were supplied through farmyard manure. The latter not only provided nutrients but kept the soil in proper physical condition. With increasing mechanization of farm operations, the animal population per unit area of cultivable land has decreased. The reduced availability of farmyard manure, increased use of mineral fertilizers, absence of green manuring practices and the lack of leguminous crops in crop rotations has resulted in the deterioration of the soil structure and lower crop yields.

Fortunately, recent advances in science offer the possibility of a new kind of technology, where fertilizer needs could be partly met by bacteria and other micro-organisms in the soil (14). One of the major efforts of agricultural scientists in the future would be to make crop plants partly independent of industrially produced nitrogen. Bio-chemical fixation of nitrogen is already well established in leguminous crops. Now the urgent need is to find new species of bacteria and other micro-organisms, or to genetically manipulate existing types to fix nitrogen in cereals and other crops.

Efforts are now being made to reintroduce the use of bio and organic fertilizers to supplement mineral fertilizers and obtain sustained crop productivity. A number of sources of bio-fertilizers, vis-a-vis *Rhizobium* bacteria, free living nitrogen-fixing bacteria, *Azospirillum*, blue-green algae, *Azolla*, *Mycorrhiza*, nitrogen fixers in non-leguminous plants and phosphate solubilizing micro-organisms are available, that can be used with great efficiency. A number of national and international research organizations are working on different aspects of bio-fertilizers and several valuable findings are at hand to be applied in crop production systems. The more important leguminous crops and their capacity to fix nitrogen in the soil are given in Table 14 (23).

Included among organic sources of plant nutrients are plant residues, animal, human and industrial wastes (cellulosic), forest wastes, city garbage and sewage, and sludge.

Farmyard manure is the most important organic manure. Its availability depends upon the animal population and the efficiency with which it is collected and preserved. An estimated 70 million tonnes of farmyard manure is produced annually in Pakistan, of which about 50% is burnt as dung cakes. The average nitrogen, phosphorus and potassium content of well rotted manure is about 1.44, 1.10 and 0.34% respectively. Poultry manure is also important because of its higher nitrogen content and easy collection.

Integrated Plant Nutrition System

In both intensive, as well as subsistence crop production systems, the farmer must aim at a balanced and efficient use of mineral fertilizers, organic manures and microbial inoculants. For the integration of plant nutrients into a productive agricultural system, optimum soil and crop management practices are of great relevance. The combined use of different sources of nutri-

TABLE 14

NITROGEN FIXING CAPACITY OF COMMON LEGUMES

CROPS	NITROGEN Plant Content (% on fresh weight basis)	NITROGEN Plant Addition to Soil (kilograms per hectare)
Sunhemp (*Crotalaria juncea*)	0.43	75
Dhaincha (*Sesbania aculeata*)	0.52	88
Guara (*Cyamopsis tetragonoloba*)	0.62	118
Senji (*Melilotus parviflora*)	0.51	113
Berseem (*Trifolium alexandrinum*)	0.43	60
Mong (*Phaseolus aureas*)	0.53	40
Masoor (*Lens esculenta*)	0.70	37
Arhar (*Cajanas cajan*)	0.66	45
Cowpea (*Vigna catjang, V. sinensis*)	0.49	58

Source: Mann, R. A., and M. Ashraf. 1985. Green Manuring in Different Cropping Systems. *Progressive Farming* 5, no. 5: 11-13.

TABLE 15

SYNERGISM BETWEEN COMPOST AND MINERAL FERTILIZERS WITH WHEAT AS THE TEST CROP

	MINERAL NITROGEN	ORGANIC NITROGEN	YIELD
	(per cent)	(per cent)	(kilograms per hectare)
T_0	control	control	1,250
T_1	100	0	2,175
T_2	75	25	2,687
T_3	50	50	3,650
T_4	25	75	2,365
T_5	0	100	2,370

Source: Sandhu, G. R. 1988. Present and Future Prospects of Bio and Organic Fertilizer Use: Country Report, Pakistan. Paper presented at Expert Consultation on Asian Network on Bio and Organic Fertilizers, 6-9 September, Bangkok, Thailand.

ents generally produces better results as is evident from data in Table 15 (31).

The use of the same quantity of nitrogen in mineral or organic manure alone gives about the same yield of wheat. The use of 25% nitrogen from an organic together with 75% from an inorganic source raised the yield by about 20%, while an application of equal amounts of mineral and organic nitrogen gave an almost 50% increase. It is also known that the beneficial effects of a single application of organic manure may last for several years. Soils around villages and close to human settlements, receiving continuous additions of organic matter, contain a relatively higher amount of humus and are much more productive.

INDUSTRIAL EFFLUENTS

Rapid, often unplanned, industrialization of the country and the lack of proper disposal of industrial effluents and municipal wastes have created many problems for human beings as well as for livestock. Industrial effluents are adding heavy metals to irrigation channels, contaminating foods and plants (34). Many industries, particularly those manufacturing chemical pesticides and caustic soda as well as industries with considerable amounts of liquid and solid industrial waste have been established without any pollution control. Toxic emissions have deteriorated rich farmland, and liquid wastes have occupied large tracts of agricultural land. A caustic soda factory near Lahore, for instance, has been leaking chlorine gas into the atmosphere and releasing tonnes of hydrochloric acid into a nearby water channel. Factories in other parts of the country are also functioning without any regard to the pollution they cause. The final repository of all these effluents is the soil.

There are about 50 metals of interest because of their toxicological effect on human health. Lead and mercury continue to be the most important, but many others, such as arsenic, beryllium, cadmium, manganese, chromium, nickel and vanadium have been of increasing concern. Certain ions such as nitrates, fluorides, sulphates also affect human health. Industries such as leather tanneries and slaughter houses may discharge waste which contain bacteria. An example is the Anthrax bacillus, originating in tanneries where hides from anthrax-infected animals are processed. Vegetable and fruit canneries may also add bacterial contaminants to streams, which can be extremely harmful. Considering the wide variety of industries established in Pakistan, any of the above mentioned pollutants can be present in untreated water. However, to what extent its presence is harmful can only be determined through sustained programmes of monitoring and analysis.

Karachi's major industries are located at four different places. The effluents of these industries are dropped into the Lyari and Malir rivers. These pollutants include salts of heavy metals, organic material as well as significant quantities of oil and grease. These industrial effluents are the major cause of the absence of plant and aquatic life in the Malir and Lyari rivers. The waters of these rivers as they enter the deltaic creeks and the sea cause marine pollution — Korangi Creek receives a heavy load of organic effluents and heavy metal salts from the Malir River (6). The data in Table 16 gives an idea of the toxicity of effluents of some of the industries situated in Karachi (33).

In Multan, the major source of industrial pollution is the Pak-Arab Fertilizer Factory which releases highly polluted waste into the Multan Canal through a *katcha* channel without any check. This untreated waste poses a serious problem to over one million acres of agricultural land. The problem is aggravated during the closure of the canal or during a low discharge period. Spillage from the *katcha* channel has affected crops in the vicinity. Animal deaths from having drunk heavily polluted water, or having grazed on affected crops, have also been reported. The effluents also appear to have affected subsoil water — drinking water from handpumps has caused intestinal diseases like dysentery and diarrhoea (12).

Other major sources of industrial pollution in Multan are the city's tannery and textile industry which dispose of waste water either on open land or dump into the Multan Development Authority's sewer system. These discharges contain excessive amounts of solids such as chromium, sulphide and dyes, that settle in the water, with the potential hazard of

TABLE 16

EFFLUENT CONTENT OF SAMPLE INDUSTRIES IN KARACHI

INDUSTRY	COPPER	CADMIUM	ZINC	NICKEL	MANGANESE	LEAD
			(milligrams per litre)			
Ahmad Food Industries	0.43	0.028	0.0238	0.270	0.73	0.320
Burma Oil Mills	0.027	0.028	2.187	0.648	0.217	0.480
Karachi Beverage Company	0.090	0.035	2.06	0.407	0.129	0.0347
Adamjee Textile Mills	0.02	0.045	5.32	0.514	0.085	—
Karachi Tannery	0.30	0.153	7.00	1.142	0.44	1.80
Indus Alkalis	0.138	0.028	0.22	1.18	0.258	0.66
Buxley Paints	0.065	0.94	0.48	0.203	0.073	3.88
Karachi Shipyard	0.28	0.10	1,342.5	0.74	5.30	11.75
Javedan Cement Industries	0.33	0.33	2.66	1.0	5.13	0.79

Source: Shah, A. A. 1987. State of Environment in Pakistan. In *Proceedings of National Seminar on Environmental Management for Sustainable Socio-Economic Development, January 25-29, Lahore, Pakistan*, 91-94. Bangkok: Economic and Social Commission for the Asia-Pacific.

sewer choking and sewer corrosion. The disposal of waste water on open land has given rise to odour problems, and has contaminated the subsoil water in the area, so much so, that drinking water obtained through handpumps is affected both in colour and taste. Effluent from the textile industry of Multan is made up of highly coloured waste water, which is extremely unaesthetic in appearance, and exerts a heavy oxygen demand on the purification capacity of the Chenab River.

Effluent-producing industries in Faisalabad number about 235. Here industrial waste is mixed with domestic waste water, with the result that municipal sewage water can no longer be used for irrigating the highly fertile agricultural land around the city. Large areas have been spoiled due to the discharge of industrial effluent on this fertile land (12).

Pollution problems at Kala Shah Kaku, outside Lahore, are even more severe. Industrial waste water is dumped untreated into the Deg Nallah which eventually joins the river Ravi. The discharge of strong hydrochloric acid and highly injurious wastes have completely destroyed the aquatic fauna in the nallah and has rendered it unfit for irrigation and livestock use.

Similar situations exist in other industrial centres of the country, where industrial effluent is contributing increasingly to environmental pollution. The conditions of the Leh Nallah which passes through the centre of Rawalpindi is extremely precarious in this respect (12). During a recent study, food purchased from the local market was found to be contaminated with lead (see Table 17) (34).

TRANSPORT AS A POLLUTANT

Transport is becoming an equally important polluting agent for agricultural products, particularly crops produced in the vicinity of major highways. Table 18 gives the lead content of forage crops harvested at different distances from the road (34). A strong negative correlation exists between distance from the road and lead content.

TABLE 17

LEAD CONTENT OF FOOD FROM RAWALPINDI

FOOD	LEAD (parts per million)
Wheat	1.20 - 4.05
Rice	0.17 - 4.90
Maize	0.17 - 4.90
Oats	0.60 - 1.00
Refined sugar	0.23 - 1.06
Gram	0.17 - 3.60
Mong (green gram)	0.34 - 2.80
Masoor (lentil)	0.35 - 3.17
Mash (black gram)	0.34 - 1.50
Chillies	0.62 - 1.76
Coriander	0.15 - 1.60
Turmeric	40.50 - 65.00

Source: Shah, F. H. 1988. Food and Feed Contaminants. *Proceedings of the Pakistan Academy of Sciences* 225, no. 1: 9-24.

PESTICIDES

The pest and disease problems of cultivated crops is as old as the agricultural profession itself. Early attempts to control pests employed naturally occurring toxic substances such as mercury and sulphur, or plant extracts like nicotine and pyrethrum. In 1939, the insecticidal properties of DDT were discovered. Since 1944, the use of pesticides in agriculture has increased rapidly, and with their introduction farm practices have undergone revolutionary changes in many countries. Today, a large number of chemical pesticides are used for the control of insects, mites, eelworms and nematodes, rats and mice, and fungal and bacterial diseases of plants and weeds. In most developed countries, including those where the environmental movement is strong, large quantities of pesticides are

TABLE 18

LEAD CONTENT OF FORAGE CROPS ALONG ROADSIDES, 1982-84

FORAGE CROP	DISTANCE IN METRES FROM THE ROAD			COEFFICIENT
	10	50	100	CORRELATION
		(parts per million)		(r)
Bajra (*Penniisetum typhoidum*)	65.0 - 82.0	38.0 - 50.0	7.0 - 12.0	–0.999
Khabal (*Cynodon dectylon*)	42.2 - 60.3	12.2 - 26.3	4.0 - 8.2	–0.999
Moonji (*Oryza sativa*)	52.1 - 70.2	16.1 - 30.2	4.1 - 8.2	–0.973
Berseem (*Trifolium alexandrinum*)	56.8 - 76.1	19.0 - 28.2	6.1 - 10.8	–0.946

Source: Shah, F. H. 1988.

still used in agriculture. The United States, for example, uses as much as 3 kilograms of pesticides per hectare, whereas Japan uses more than 6 kilograms per hectare. Even in India the present consumption of chemical pesticides is about 500 grams per hectare (14).

In Pakistan the use of pesticides has increased manifold over the past decade, particularly for crops like cotton, rice, sugar cane, tobacco, fruit and some vegetables. In all these cases, both productivity and total production has undergone a phenomenal development. The basic manufacture of pesticides is practically non-existent in Pakistan, with the exception of DDT and BHC, and the country continues to depend heavily on the import of various types of products. The data in Table 19 illustrates the trend in the import of pesticides.

About a dozen companies are at present engaged in the marketing and distribution of pesticides in the country. Out of these, eight have developed their own formulation facilities, mostly with technical assistance from their foreign principals. According to the statistics of the Pakistan Agriculture Pesticides Association, the consumption of liquid, granular and dust-power types of pesticides has registered a steady increase over the past decade.

The incidence of disease and insect pests have increased as new high yielding varieties of rice, wheat and other major crops were introduced to boost agricultural production for self-sufficiency. These varieties, requiring closer plant spacings and higher fertilizer applications, are often more susceptible because of their more luxuriant growth. In Japan, the introduction and dissemination of high production technology in rice, has gradually led to increased pest infestation since the years 1956 and 1970 (22). In Pakistan pre- and post-harvest crop loss from pests alone is estimated to be around 35%

TABLE 19

IMPORT OF PESTICIDES

YEAR	QUANTITY	VALUE
	(thousand kilograms)	(million rupees)
1980-81	7,083	224.23
1981-82	5,481	230.62
1982-83	8,860	396.71
1983-84	10,662	685.84
1984-85	15,889	1,196.62
1985-86	17,498	1,416.80
1986-87	20,647	1,878.04
1987-88	15,765	1,769.27
1988-89	11,326	1,382.29

Source: *Agricultural Statistics of Pakistan*, *1988-89*.

of the total harvest. In terms of money, this is worth over Rs. 36 billion, which is a colossal loss for a country like Pakistan.

But the indiscriminate use of chemical pesticides to minimize agricultural losses has created problems. Pesticides, if not applied properly, do not necessarily hit the target. During the United Nations Food and Agriculture Organisation's Pest Conference in 1975, it was pointed out that about 95% of the insecticides applied to crops either go into the soil or remain in the atmosphere and only 5% fall on the plant. The residue pollutes the environment — creating problems of pest resistance and, in some cases, of severe damage to human health through the ingestion of toxic chemicals absorbed through the food chain.

The use, overuse or misuse of pesticides is causing disabilities and deaths not only in industrialized countries but, to an increasing extent, in developing countries also. At a United Nations seminar in Nairobi, Kenya in 1984, it was revealed that as many as 370,000 people suffer from pesticide poisoning and about 10,000 die annually due to pesticides. According to the World Health Organisation 500,000 people are poisoned by pesticides each year and about 5,000 of them die annually (3).

Besides considering the direct effects of pesticides on the environment, one must examine their indirect influence on air, water, food, soil and target and non-target organisms also. The indirect risks often go unnoticed. These include damage to animals, birds and fish as well as to useful insects, from treatment of crops or from traces of pesticides remaining in the environment after the spraying operation.

The manufacturing process, moreover, is usually very complex and there is the hazard of pollution around production plants. The impact of such hazards can be judged by the Bhopal tragedy of 1984, where a leakage of methylisocyanate from a pesticide factory killed over 2,000 people and adversely affected over 60,000 others (12).

Chemical contaminants can be dispersed in air at normal temperatures and pressures in gaseous, liquid and solid forms. The latter two forms represent suspensions of particles in air, and have been given the name of 'aerosols'. Air contamination can also result from a major release due to an explosion or some industrial accident. A factory explosion in Seveso, Italy, in July 1976 spread the highly toxic chemical dioxin, on the windward side, over a considerable distance. The extent of contamination was not disclosed to the affected farmers, who continued to graze their animals on contaminated ground. As a result contaminated milk and eggs arrived in the market and were consumed by many.

There are over 50,000 chemical substances in more than one million combinations in the world market. Though all are not hazardous, a great number of chemical products and their by-products are highly toxic, carcinogenic, teratogenic, mutagenic and in many cases bioaccumulative. It is pertinent to point out that contamination by pesticides is directly related to their degree of persistence in the environment which is mainly determined by characteristics of the pesticidal compounds themselves.

Despite these hazards, the use of toxic chemicals seem to be increasing daily. Several accidents have occurred since synthetic organic chemicals were introduced as pesticides. As a result, many chemicals found to have adverse effects, have been deregistered in the United States and several other countries, and a few in Pakistan also.

The challenge to agriculturists, concerned about practising sustainable agriculture, is to develop alternative approaches to pest control which minimize the danger of contamination and persistence in the environment inherent in the use of agro-chemicals, and at the same time effectively control the development of potential pests. Although pesticides continue to be used as an essential part of the technology for high productivity, increasing pressure from environmentalists will combine with the economic logic of profit to compel farmers and scientists to search for alternative ways to handle pest problems. At present, technology has not always been contributing to progress in this direction.

For example, herbicide use is increasing with the 'minimum tillage' movement. However, there is increasing recognition of the need to promote techniques to raise productivity without using environmentally damaging chemicals and practices. With this understanding, alternatives to the prevailing models for 'modern' and 'commercial' cultivation practices are being adopted along with other approaches to pest control. Many of these involve a belated appreciation of the wisdom of 'traditional' farming systems.

It still remains to be seen how industry responds to criticism of present pesticide technologies, and what approaches it offers to resolve economic and environmental problems. Pesticide manufacturers would be well-advised to appreciate the emergency realistically. Present pesticide practices have proved to be socially unacceptable, technologically inefficient, economically unsound, and environmentally unsustainable. Alternative solutions must, therefore, be developed for more sustainable agriculture.

AGRICULTURE AND ENERGY

Energy and energy resources have always played a vital role in the economic development of a country. In fact, the per capita consumption of energy is considered a reflection of the country's living standards, prosperity and economic growth. The consumption of energy in Pakistan has been increasing steadily since Independence; it recorded a growth rate of 4.8% per annum between 1961-74 and 7.2% per annum between 1974-81. Although there has been a more than tenfold increase in the consumption of energy since Independence, the current per capita consumption rate of 0.673 tonnes of coal equivalent (TCE) is still very low and is only one-ninth of the world's, 1/42 of the United States and 1/46 of Norway's average per capita consumption.

The world's consumption of commercial energy increased from an estimated 2.4 billion TCE per year in 1950 to about 9 billion TCE in 1975. It is expected to increase to 40 billion TCE per year by the year 2030 (16). The average per capita consumption of energy, in the world, is projected to increase from about 2 TCE per year in 1975 to a level of 3 and 5 TCE per year in 2030, for low- and high-use scenarios respectively.

After the first energy crisis in 1973, the world suddenly became aware of the vulnerability of its total dependence on only one form of energy. The crisis put a heavy strain on the economies of non-oil producing countries. In Pakistan, the import bill for petroleum rose from Rs. 257 million in 1971-72 to close to Rs. 20 billion by 1982-83 and has since then fluctuated around that figure. The total energy available for consumption in Pakistan during 1988-89 was 22.79 tonnes of oil equivalent. Its consumption, by major sectors of the economy is given in Table 20.

The main sources of energy in Pakistan include oil (40.2%), natural gas (37%), hydel power (13%), coal (9.4%) and nuclear power (0.4%) (21).

The most important domestic sources of energy are gas and hydropower. There are at present 14 gas fields with estimated recoverable reserves (at the end of March 1990) of 500 billion cubic metres. The 10 operating gas fields together produced 12.8 billion cubic metres of gas in 1988-89. Of this 36% was consumed by the power generating stations, 26% by the fertilizer industry, 21% by general industries and about 13% went to domestic consumption.

The main sources of hydel power are the Tarbela, Mangla and Warsak Dams, having an installed generating capacity of 1,759 megawatts (MW), 800 MW and 243 MW respectively.

At present, the share of oil in the total energy supply is about 40% (this includes imported oil). The country's recoverable oil resources are estimated at 108.9 million barrels. During 1988-89 the domestic production of oil amounted to 17 million barrels at an average extraction rate of 46,767 barrels a day. About 80,000 barrels per day are imported to meet the total demand (37).

Coal is another source of commercial energy. The coal reserves in the country have been estimated at 9 billion tonnes. Quality-wise this

TABLE 20

ENERGY CONSUMPTION BY SECTOR

SECTOR	YEAR 1982-83		YEAR 1988-89	
	(million tonnes of oil equivalent)			
Domestic	2.22	(14.5%)	4.39	(18.2%)
Commercial	0.47	(3.1%)	0.75	(3.1%)
Industrial	4.55	(29.8%)	6.57	(27.2%)
Agriculture	0.77	(5.0%)	1.35	(5.6%)
Transport	2.99	(19.6%)	4.58	(18.9%)
Power	2.50	(16.4%)	4.88	(20.2%)
Fertilizer	0.75	(4.9%)	0.80	(3.3%)
Others	1.02	(6.7%)	0.86	(3.3%)
Total	**15.27**	**(100.0%)**	**24.18**	**(100.0%)**

Source: *Economic Survey 1989-90.*

coal can be classified as highly volatile to sub-bituminous, with a relatively high ash and sulphur content. At present about 98% of the total production of coal is being used in the brick kiln industry. A small quantity of coal is also being used in thermal power plants.

The supply of electricity in Pakistan comes from hydroelectric as well as thermal power plants. The hydroelectric potential of Pakistan is dependent upon the river Indus and its tributaries, and is theoretically estimated at about 18,000 MW. Of this only 2,803.54 MW is presently being utilized. The consumption of electricity is dominated by the industrial sector. In the agriculture sector, running tube-wells with electricity has been given a priority in recent years, but the growth rate in usage does not exceed the overall growth rate (29).

Renewable Resources

Among the renewable sources of energy, solar energy captured by plants through the process of photosynthesis is the most important one, especially since the latter is a key process in producing plant biomass. Plant-based energy systems are not only renewable but also remove carbon dioxide from the atmosphere, helping contain environmental pollution (19). The carbon dioxide content of the atmosphere has increased from 290 ppm in 1860 to 330 ppm in 1980. At the present rate of fossil fuel consumption, about 5 billion tonnes of carbon are released into the air every year. This is equivalent to an increase, in atmospheric carbon dioxide, of 0.3% per year. This pollution has also increased atmospheric temperature. Over a longer period, these changes are bound to affect agricultural production systems and their output. A possible solution to this problem is to increase the photosynthetic productivity of vegetable raw material, which would not only convert physical energy into chemical energy but reduce the amount of carbon dioxide in the atmosphere while generating oxygen, the life-sustaining gas. Hence increases in photosynthetic efficiency would automatically increase the amount of organic matter available as biomass and biofuel: firewood, vegetable oils, hydrocarbon plants, freshwater weeds, sewage grown algae, algal hydrocarbon and biological production of hydrogen using halobacteria, algae, azolla and even higher plants.

Wood meets half of the total domestic energy requirements of the country. The current annual consumption of firewood is estimated to be 19.70 million cubic metres, which will rise to 30.66 million cubic metres by the the year 2000. The housing census carried out in 1980, reports that 70% of the total households in Pakistan use wood for cooking and heating, while in rural areas the dependence goes upto 80%.

With increases in the price of wood, charcoal and alternate fuels, people are indiscriminately cutting and selling trees on a large-scale, causing extensive deforestation. There is a wide difference between the perception of a villager and a national planner about the firewood crisis. The former sees it as a local problem and feels that wood is a 'gift of god', and he has every right to use it, even to the extent of felling it illegally. The latter sees it as a problem leading to denudation of forests and ecological disaster. Table 21 shows the average annual deforestation in some Asian countries. In all cases the rate of afforestation or regeneration of forests is much lower than deforestation.

The burning of cow dung is yet another disastrous effect of fuelwood scarcity. This practice results in the loss of valuable plant nutrients and organic matter contained in cow dung. It is claimed that if the cow dung being burnt as fuel could be spared and applied to agricultural fields, the resultant increased food production would be more than enough to meet the food deficit in the country (36). In Pakistan about 50% of animal droppings are burnt as dung cakes. This corresponds to 29.93 million cubic metres of firewood. Hence, in order to save 34.55 million tonnes of cow dung annually for use as fertilizer this country will have to produce an additional 29.93 million cubic metres of fuelwood (36).

Bio-conversion of organic materials, such as animal dung, farmyard waste, tree leaves, algae and municipal refuse in a biogas plant yields methane gas for burning and sludge for manure, thus providing a renewable source of energy and fertilizer. Rough estimates show that one tonne of dry organic matter can be converted into almost two barrels of oil and/or about 280 cubic metres of gas, plus 0.73 tonnes of fertilizer, through anaerobic fermentation in biogas plants (12). The number of large animals (buffaloes and cattle) in Pakistan is around 31 million. Theoretically the dung from these animals could supply energy the equivalent of approximately nine nuclear power stations of 400 MW each. The potential of harnessing energy from about 25% of livestock droppings is

TABLE 21

DEFORESTATION IN ASIA

COUNTRY	ANNUAL DEFORESTATION (thousand hectares)
Bangladesh	8
Bhutan	2
Brunei	7
Burma	95
India	147
Indonesia	850
Kampuchea	15
Laos	125
Malaysia	230
Nepal	84
Pakistan	**7**
Papua New Guinea	21
Philippines	101
Sri Lanka	25
Thailand	333
Vietnam	65

Source: Sheikh, M. I., and M. Amjad. 1985. Creation of New Resources for Fuelwood and Wood Energy. *Progressive Farming* 5, no. 5:19-26.

certainly there. If processed through biogas plants this will not only yield 27 million cubic metres of gas per day but also about 40 million tonnes of wet manure annually (12).

Over the years, various fields of science have discovered a variety of approaches to convert radiant energy from the sun directly into useful power. Each approach has its own advantages as well as disadvantages, and its own unique relevance and acceptability. Presently, efforts are being made to use solar energy in the following three areas (28).

- Solar cooling, heating and hot water supply systems.
- Solar thermal power generation systems.
- Photovoltaic power generation systems.

In Pakistan abundant sunshine is available throughout the year for conversion into electricity through a photovoltaic system. Remote villages which cannot be hooked up to the national grid are being electrified through the use of photovoltaic cells. The present units, set up in all the four provinces, have a generating capacity of 434.10 kilowatts (KWp) (37). On the whole, solar energy can provide between 40% to 60% of the total energy requirement but the system has to be boosted by alternate sources of energy in cloudy weather.

Wind energy is another source that can be tapped. An equivalent of 100 billion watts per year of power, in the shape of wind energy, is available on earth. At sea, winds are even stronger than on land. For suitable windy regions and particularly coastal areas, windmills can be installed to produce mechanical energy. Traditionally windmills have been in use in China, Iran, the Mediterranean and Northern Europe for a variety of purposes. In Denmark, a 200 KW wind-driven generator, connected to an alternate current network has been running successfully for the past several years (2). In Pakistan, so far, four mechanical wind pumpers and one wind power generation system with a capacity of 10 KWp in Sindh, and one wind power generation system of 2 KWp in Balochistan have been installed.

One may mention here, that the contribution of renewable sources of energy would be very small, unless the cost of existing technologies decreases substantially, or the cost of competing fuels, especially oil, rises substantially.

AGRICULTURE AND FORESTRY

Forests constitute one of the most important renewable natural resource of a country. Besides offering magnificent scenic beauty, which sharpens human imagination, they exert a moderating effect on climate. In addition, they play a productive as well as a protective role. The former includes provision of timber, firewood, forage for animals and raw material for several small- and large-scale industries such as pharmaceuticals, chemicals, housing, rayon, resin, paper, hardboard, plywood, safety matches, sport goods, paints and varnishes. The protective role of forests is manifest in the conservation of soil and water in mountain areas covered with trees.

The area under forests in Pakistan is far below the minimum considered essential for balanced economic growth and environmental stability. Ideally, 25% of the area of a country should be covered with trees whereas in Pakistan it is only about 3.8%. Of the total forest area only one-third is productive forest, the remaining is maintained as protective cover. The heaviest pressure on forests comes from the need for timber and firewood. The chances of expanding the area under forests being limited, the country has to manage and exploit its existing stands more efficiently to increase its forest wealth. The ecological benefits of forestry are of vital importance to rural development in general, and agricultural development in particular. Low agricultural productivity is common in countries where forest resources are neglected.

Trees are essential for the stability of an agricultural system of a country like Pakistan. The flow of rivers that makes the vast and complex irrigation system viable is ensured and regulated by trees that cap mountain slopes and watersheds. Sandstorms and desiccating winds emanating from deserts play havoc with agricultural crops and orchards. These adverse effects can be considerably reduced and even completely mitigated by trees planted in the form of a shelter-belt or strategically located over a farm. Similarly damage to orchard trees, from frost and icy winds at night, can be minimized by an umbrella of large trees planted in the right spots. It would not be wrong to say that agriculture cannot develop and prosper without adequate tree cover on mountains, plains and farmlands.

Because of their size, trees play a significant role in the cycle by which nutrients from the soil are made available to crops — the weathering of rocks helps in the gradual release of minerals and the slow removal of nutrients through leaching by rainwater. The roots of trees can go much deeper into the soil and are able to draw nutrients and water from the deeper strata which other plants cannot do. Thus, in the absence of tree cover, the transfer of elements from deeper layers to top soil is considerably reduced. Falling leaves and fruits are a regular source of nutrients to the soil while the tree canopy protects the soil from the direct impact of sun, rain and wind.

Some developing countries in South-East Asia and Africa have turned to agro-forestry systems to solve the problems of low yields because of poor soils and a shortage of fuelwood and timber. Under this system, crops are grown between permanent rows of fast growing tree species (40). Agro-forestry can be beneficial in many ways. Leguminous trees are able to fix atmospheric nitrogen in the soil, and their leaves and branches can be mulched to provide additional nutrients to growing crops. In trials at the International Institute of Tropical Agriculture in Nigeria, Leucaena tops added to the soil contributed over 200 kilograms of nitrogen per hectare in two years, giving yields of over 2,800 kilograms of maize per hectare (8).

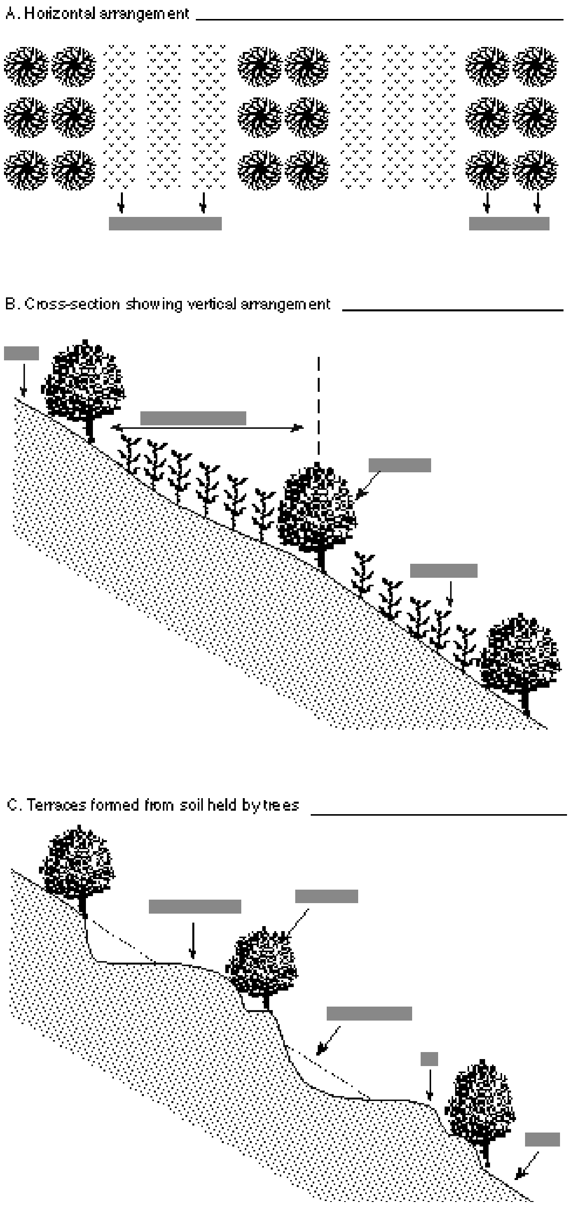
In semi-arid Africa, trees can help restore the land to productive use. The indigenous tree species *Acacia albida*, a legume, is a valuable component of a mixed-farming system that in addition to trees includes millet, sorghum, and cattle. In Sudan, where acacia was left in the fields, millet could be grown continuously for 15 to 20 years, compared to only three to five years without the trees. In Senegal, it was found that when the crop-livestock-tree system was kept in balance, the land could support 50 to 60 people per hectare (several times more than the average for the region) with continuous cropping and no loss of soil productivity. Some agro-forestry patterns along with the beneficial tree-crop interactions are depicted in Figures 2 and 3.

Unlike crop culture operations where large quantities of plant nutrients are removed from the soil along with the harvest, exploitation of forests for wood, if properly managed, has little effect on soil quality. Wood is precisely that part of the tree in which nutrients are least abundant. Cutting and felling operations can be made more beneficial, and improve soil productivity, if the nutrient-rich bark, small twigs, branches and leaves are removed from the trees and logs before transportation and left on the site as ground cover.

To reduce fuelwood pressure on state forests and to enhance the income of resource-poor farmers, many tree species can be planted successfully on homesteads and farms. Besides fulfilling the need for fuelwood they can also serve the purpose of live-fencing, soil improvement (through nitrogen fixing and nutrient recycling), soil reclamation, erosion control, flood control, protection of irrigation works, consolidation of water channels, improvement of local environment, landscaping, shade trees, wind breaks, host trees for silk or lac cultivation and source of wood for agricultural implements. Easy propagation, ability to withstand constant coppicing and natural resistance to stress conditions add to the value of multi-purpose trees. Many of these can be grown on marginally useful land. Some examples of multipurpose trees that can be planted in the country in various eco-zones are: *Acacia albida, A. modesta, A. nilotica, A. seyal, Azadirachta indica, Emblica officinalis, Eucalyptus* spp., *Leucaena leucocephala, Mangifera indica, Morus alba, Pinus roxburghil, Pithecolobium dulce,* Poplars, *Salmalia malabarica, Sesbania* spp., *Tamarindus indica* and *Zizyphus mauritiana.*

FIGURE	2

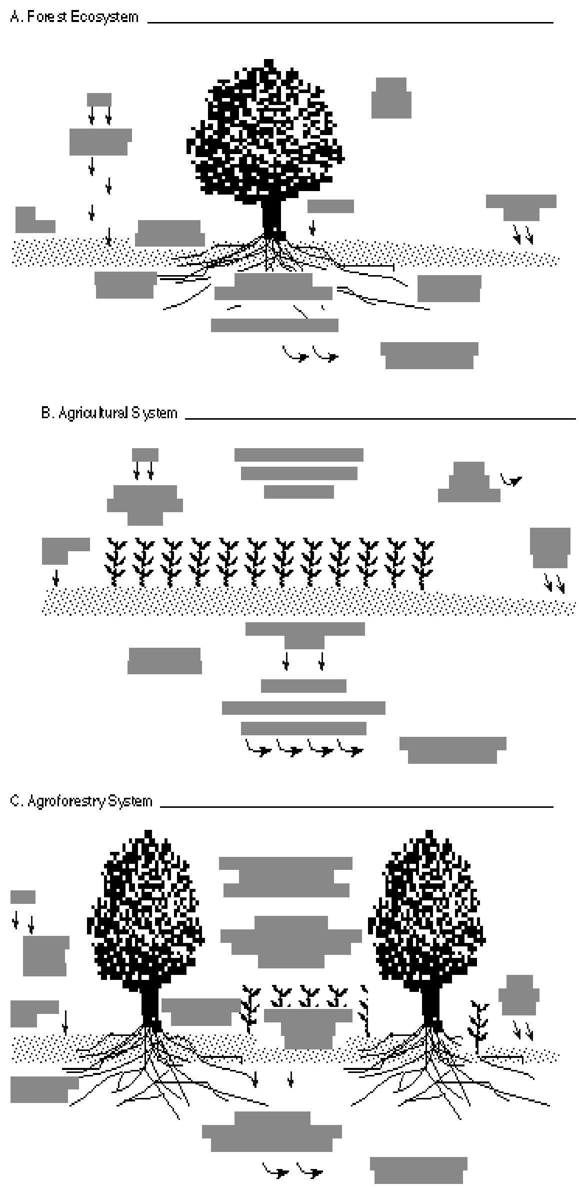
STRIP CROPPING WITH TREES TO FORM NATURAL TERRACES



Source: Vergara, N. T., ed. 1982. *New Directions in Agro-Forestry The Potential of Tropical Legume Trees.* Honolulu, Hawaii: Environment and Policy Institute, East-West Centre.

FIGURE	3

ADVANTAGES OF AGROFORESTRY IN COMPARISON WITH FORESTRY AND AGRICULTURAL SYSTEMS



Source: Nair, P. K. R. 1982. Some Considerations on Soil Productivity under Agro-Forestry Landuse Systems. Paper presented at 12th International Congress of Soil Science, February, New Delhi, India.

It has been estimated that 12 trees per hectare could be planted on each farm in the shape of windbreaks or along water channels, paths, or in small woodlots. If fast-growing trees like poplar, eucalyptus, siris, etc., are planted with a spacing of 5x5 metres on a 10-year rotation basis, an average yield of 0.425 cubic metre per tree per year can be obtained (40). This can result in an additional annual production of 10.1 million cubic metres of wood from culturable waste areas. If one-tenth of this is planted with conventional hardy and adapted, but comparatively slow-growing species like shisham, kikar, bakain, etc., with 5x5 metres spacing, an average yield of 4.84 cubic metres per hectare yearly can be obtained with a total production of 11.95 million cubic metres of wood annually. The production of wood can thus be increased enormously if these sources are fully exploited.

The only option of restoring the degraded environment is through the adoption of agro-forestry with the purpose of sustained land management, and increasing overall productivity through a combination of crops, trees and animals on the same unit of land.

AGRICULTURE AND LIVESTOCK

Livestock is an important sub-sector of Pakistan's agriculture. At a constant factor cost of 1986-87, with its share worth Rs. 6.2 billion of the national product, it contributed 30% of the total value of agriculture. Its share in GDP stood around 8% (10).

Livestock rearing is an important occupation in which around 50% of the rural population is engaged. Animals are owned in small herds by some 5 million farm households, and by about 0.8 million landless families. Livestock and their products provide a significant source of food as well as regular cash income to the rural population. The livestock population of the country is presented in Table 22.

Pakistan has some of the world's best breeds of dairy animals such as the Nili-Ravi buffalo, the Red Sindhi and Sahiwal cattle and other breeds of cattle and small ruminants. They provide roughly 13 million tonnes of milk and milk products, 1.3 million tonnes of meat and over 4 billion eggs per year. The per capita availability of major livestock products is given in Table 23.

TABLE 22

LIVESTOCK POPULATION , 1988-89

LIVESTOCK	NUMBER (million head)
Buffaloes	14.3
Cattle	17.2
Sheep	28.3
Goats	34.2
Poultry (rural and commercial)	164.6
Equine and Camels	4.9

Sources: *Economic Survey 1989-90*; Livestock Census of Pakistan, Agriculture Census Organisation, 1989.

Livestock also provides motor power for farm operations, farmyard manure for crops and integrates the use of family labour. Some 6 million work animals are maintained for tillage, irrigation and carting which provides around 70% of the energy input on farms.

If the energy input of work animals and the fuel and fertilizer value of dung are taken into account, the total contribution of livestock to GDP from agriculture could be considerably more than the officially stated figure of 30%. It has been estimated that over 30 million cattle and buffaloes in the Indus Basin produce about 18 million tonnes of dry dung each year, which contain 0.3 million tonnes of nitrogen. If this dung is used as fuel, it would deliver 10 billion kilocalories to cooking pots on inefficient earthen stoves (efficiency only 11%), most commonly used in the rural areas (11).

This fairly large livestock population holds great potential for development. If the existing national livestock herd could be adequately fed, it could produce at least 30% more milk and meat (9).

TABLE 23

PER CAPITA AVAILABILITY OF MAJOR LIVESTOCK PRODUCTS

YEAR	MILK	MEAT	EGGS
		(kilograms)	(number)
1982-83	88	10.6	36
1983-84	90	11.0	39
1984-85	92	11.4	43
1985-86	96	11.9	48
1986-87	98	12.2	37
1987-88	101.2	13.9	38
1988-89	104.4	14.3	39

Source: *Economic Survey 1989-90*.

This would help ease the problem of keeping up with increased demand for animal protein (eggs, milk and meat) arising firstly, from an ever-expanding population and secondly, from a gradual rise in the per capita income. Pakistan ranks first in the Asia-Pacific region insofar as per capita milk availability, but the same is not true for red meat availability in the country. The latter is partly ascribable to the fact that livestock resources have not yet been fully exploited.

Milk is an important item of human diet. It is not only highly nutritious but is also considered a complete food. It provides 60% of protein and 36% of energy, in addition to vitamins and minerals. It is a staple food for infants, children, the aged and invalids. The daily per capita availability of milk in Pakistan, is estimated at 204 grams which is less than half what is available in some developed countries. The availability of milk, however, is not uniform. Because of the absence of a well-organized milk collection and marketing system, supplies of milk to urban areas is inadequate, with the result that fairly large quantities of powdered milk are being imported regularly to bridge the gap between supply and demand, particularly in cities. The amount being spent annually on the import of powdered milk and other dairy products is shown in Table 24.

The livestock population at present is under severe nutritional stress, as the base for its feed supply has been progressively eroding. The area under fodder crops has been reduced by one million acres in the irrigated tract during the past decade or so, drastically upsetting the balance between livestock numbers and feed supplies. Livestock is sustained on different sources of feed which vary from season to season, and from one ecological zone to the other. At present, the area under cultivated fodder is 2.71 million hectares which produces approximately 17.44 million tonnes of fodder as dry matter (DM). Crop-wise, fodder yields and total production are given in Table 25.

Crop residues are also fed to livestock: about 35.85 million tonnes are produced from wheat, rice, barley, oats, maize, sorghum, millet and rice. In addition, the production of cake/meal and concentrates from cotton and other oilseeds is estimated at 1.8 million tonnes.

Rangelands provide another 25.4 million tonnes DM to livestock (26). It is estimated that *shamilaats* (village communal grazing), *belas* (riverine grazing belts) and irrigated plantations

TABLE 24

IMPORT OF MILK AND MILK PRODUCTS

YEAR	VALUE	% INCREASE OVER 1981-82
	(million rupees)	
1981-82	391	100
1982-83	581	149
1983-84	579	148
1984-85	520	133
1985-86	475	122
1986-87	546	140
1987-88	410	105
1988-89	606	155

Source: *Agricultural Statistics of Pakistan, 1988-89*.

TABLE 25

CULTIVATED FODDER CROP PRODUCTION IN PAKISTAN

CROP	AREA	DRY MATTER	
		Yield	Total Production
	(million hectares)	(tonnes per hectare)	(million tonnes)
Sorghum	0.51	5.92	3.01
Millet	0.11	2.88	0.31
Guar	0.31	4.56	1.41
Maize	0.05	7.84	0.39
Other kharif fodder	0.50	10.02	5.01
Berseem	0.82	5.50	4.51
Lucerne	0.15	8.00	1.20
Shaftal	0.03	4.96	0.15
Rape and mustard	0.02	4.71	0.09
Other rabi fodder	0.21	6.51	1.36
Total	**2.71**		**17.44**

Source: Mohammad, N. 1988. *Rangeland Management in Pakistan*. Kathmandu: International Centre for Integrated Mountain Development.

provide about 2 million tonnes of dry forage.

Forage yields with total digestible nutrients (TDN) and digestible proteins (DP) are given in Table 26. To feed almost 99 million head of livestock, approximately 45 million tonnes TDN and 5 million tonnes DP are required. There is, thus, a shortage of about 25% TDN and 37% DP.

As mentioned earlier, an expansion in the area under cultivated fodder crops is not possible. However, rangelands, which constitute over 60% of the total area of Pakistan, are a way to feed the increasing livestock population. Currently, rangelands provide about 60% of the total feed requirement for sheep and goats, 40% for horses, donkeys, camels, and 5% for cattle and buffaloes.

But, because of over-grazing and improper management, these rangelands are producing 50%, or even less, of their productive capacity (39). At present, these are stocked with twice the number of animals that these areas can support. The actual stocking rate at some places may be higher, perhaps three times the carrying capacity, because the animals are not evenly distributed over the entire area of grazing lands. There are vast areas which are not grazed because of inaccessibility, lack of water, extremely harsh climate, and other similar reasons.

In addition to serving as a feed production base for livestock, rangelands also form part of highly important catchment areas of various rivers and streams. About 40% of the watershed areas, which drain into big dams like Tarbela and Mangla, are rangelands. These dams produce 70% of the total electric power in the country and supply water to the irrigation network (27).

Range management thus remains a serious unresolved problem, with important implications not only for livestock, but for the water and agriculture sectors in general also. For sustained production of quality livestock, and to raise the

TABLE 26

FEED RESOURCES IN PAKISTAN

FEED	DRY MATTER	TOTAL DIGESTIBLE NUTRIENTS		DIGESTIBLE PROTEIN	
	(million tonnes)	(%)	(million tonnes)	(%)	(million tonnes)
Fodder crops	17.50	60	10.57	10.0	1.75
Cereal crop residues, straw, etc.	35.85	30	10.76	2.0	0.70)
Crop by-products, etc	3.00	30	0.90	2.0	0.06
Cereals, legume seeds & their by-products	4.60	70	3.22	7.0	0.31
Oil-seed cakes & other protein concentrates	1.80	70	1.26	18.0	0.31
Rangelands at 60% utilization of available forage	15.30	50	7.65	4.5	0.69
Total	**78.05**		**34.36**		**3.8 2**

Source: Mohammad, N. 1988.

level of per capita protein consumption, concerted efforts are needed to improve the management of this highly delicate plant-livestock system. However, the viability of any effort in such a complex ecosystem cannot be guaranteed until the participation of the local population is also taken into account.

Poultry Production

Commercial poultry production in Pakistan started in the early 1960s with the introduction of hybrid-layer and broiler stocks. The initial development was slow, but from the early 1970s it has grown phenomenally, averaging about 15% both for poultry meat and eggs. This pattern of growth is expected to continue in the future. Consumer acceptance, availability of poultry feed at competitive prices and the emergence of an organized marketing structure for poultry and poultry products *inter alia*, gave a strong boost to this industry. There are over 10,000 commercial poultry farms operating within the country. More than 300 breeding farms and 150 hatcheries produced 246 million day-old chicks of exotic breeds during 1988-89. Nearly 60 million broilers are raised for meat providing an estimated 1.1 kilogram of poultry meat per head per annum. The per capita annual availability of eggs has increased from 7 in 1964 to 39 in 1988. More than 100 feed mills, with a capacity of 1.4 million tonnes of compounded feed, are working within the country.

MOUNTAIN ECOSYSTEM AND WATERSHEDS

Watershed are broadly defined as habitable areas of the earth which are beyond the limits of well-defined agricultural lands and urban areas. This habitable land surface, generally residual in character, is often classed as forest or rangeland, wildland, marginal land or simply undeveloped land. For lack of a more generic term, these areas are usually called watershed lands, and constitute more than 80% of the earth's 10 billion hectares land mass.

About three-quarters of Pakistan's total geographical area of 79.6 million hectares comprising mountains, watersheds, and arid tracts are uncultivated. In many significant ways the productivity of the cultivated areas and the well-being of the people living there depends on the management of these uncultivated areas (29). The watershed areas are in a depleted condition and far below their productive potential. Because of deforestation, over-grazing and extension of cultivation into marginal areas, watershed lands have been severely damaged. All these areas have been adversely affected by varying degrees of wind and water erosion, resulting in substantially reduced agricultural production.

The mountainous region of Pakistan can be divided into three hydrological units: the upper Indus system, the closed basins of Balochistan, and the Makran coastal drainage system. Among these three watershed regions, the upper Indus system comprising the Northern Areas, the province of the NWFP, northern Punjab, as well as the State of Azad Jammu and Kashmir, constitute the most important and complex watershed in Pakistan. Watershed resources in this area provide irrigation water to the Indus plains and are also a major source of hydropower in the country. The importance of this watershed can be judged from the fact that when the country faced a water-shortage crisis in 1985-86, many canals had to be closed, and the power houses at Mangla and Tarbela failed to generate adequate electricity. As a result, cotton planting received a serious setback, and to cope with the shortage of electricity the country had to resort to loadshedding. This badly affected the running of tubewells for irrigation and the functioning of industrial establishments, with a colossal negative impact on the national economy.

The watersheds of the Indus Basin rivers have suffered from excessive felling of woody vegetation and heavy over-grazing in the past. Land even upto 2,400 metres altitude and not suitable for this purpose, is cultivated. Several million tonnes of soil are removed from watersheds by water erosion. This sediment is subsequently deposited in streams, channels, lakes, reservoirs and harbours, requiring costly remedial measures to continue functioning. Sediment studies in the early 1970s showed that soil at the rate of 4-7 thousand tonnes per square mile was being carried annually in the rivers Chenab and Jhelum (4). According to recent estimates the sediment load in the Indus is greater, and in fact, is one of the highest in the world. Estimates of annual soil loss on unprotected land in the NWFP, averages about a tonne per acre. Likewise, on several of the steeper, more critical parts of the Tarbela catchment in the Punjab, soil erosion has been measured at 2-4 kilograms per square metre annually.

The Tarbela Dam had a capacity of 11.62 MAF immediately after its construction in 1974. In 1984 this had been reduced to 10.03 MAF due to sedimentation. Recent estimates show that the annual sedimentation rate per square kilometre of the catchment area of Tarbela and Mangla reservoirs is 167 cubic metres and 48 cubic metres respectively. At the current rate of sedimentation the projected life of Tarbela has decreased from 100 to 80-90 years. Much of the sediment is in the form of bedload which cannot be checked by land treatment alone. An evaluation of the impact of watershed management activities undertaken in the Mangla catchment has indicated that the economic life of the Mangla reservoir has been lengthened by about 60 years, through reduction in soil erosion and siltation rates achieved during the past 25 years. Rawal Dam constructed in 1960 with a capacity of 47,500 acre-feet and a catchment area of 106.25 square miles, has lost 10,000 acre-feet capacity due to sedimentation (4).

Besides reducing the capacity of the reservoir to generate hydropower and provide irrigation water, water loaded with sediment from the catchment areas also causes severe floods in areas where there are no dams. These floods cause colossal loss of life and property and heavy damage to irrigation networks, crops, communication systems of roads and railways, and utilities such as electricity and telephones. A severe flood in 1955 inundated 2,420 villages, killed 400 people and 70,000 cattle, and led to damage estimated at Rs. 83 million (4). There have been many such floods causing enormous destruction of life and property. Between 1973 and 1978, five severe floods occurred in the

Punjab and Sindh provinces affecting 12.7 million people, inundating over 8 million hectares of land and destroying about 70% of the standing crop. This resulted in subsequent food deficits and heavy import bills. Floods occurring in September and October 1988, damaged vast areas of the Punjab province. These inundated more than 3,000 villages, causing extensive damage to the crops.

The above facts indicate that the country's survival is critically dependent on proper management of mountain watersheds. This would include measures avoiding intensive cultivation on the steeper slopes, proper and judicious approaches for road construction, cutting and extraction of timber, and grazing of animals. Most of the people living in watershed areas are poor and generally subsist on income from marginal agriculture and cattle grazing. Therefore, unless they are provided with alternate means of livelihood, management practices cannot yield the desired results.

AGRICULTURE AND DESERTIFICATION

There are many factors responsible for the spread of desertification in Pakistan. However, the primary reason is low rainfall accompanied by over-exploitation of resources. Pakistan is, by and large, a semi-arid to arid country with 68 million hectares of land lying in regions where the annual rainfall is less than 300 millimetres. The extent of arid regions in various provinces of the country is given in Table 27 (5).

The quest for greater productivity has intensified exploitation and has carried disturbance by man into less productive and more fragile marginal lands. During the past 30 years more land has been brought under cultivation. Farmers have increased the net area sown by 40% since 1947-48. It is generally believed that additional land presently classified as waste land can be converted into cropland. However, this conversion of the natural terrain to agricultural fields, is invariably accompanied by erosion, flooding and pest outbreaks. As the plains are exhausted, slopes are brought under cultivation. Natural vegetation is removed, exposing and loosening the soil. Even when properly terraced, such land is easily eroded to gullies by rain and wind. Conversion of marginal land to agriculture, also leads to an increase in pests as their natural predators and competitors are eliminated, either directly or by habitat destruction. The removal of vegetation also increases run-off, causing floods that damage the crops in the plains.

TABLE 27

DISTRIBUTION OF ARID REGIONS IN PAKISTAN

PROVINCE	ARID	SEMI-ARID	SUB-HUMID	OTHER	TOTAL AREA
			(square kilometres)		
Punjab	119,310	59,678	17,014	10,197	206,199
Sindh	134,896	6,018	—	—	140,914
Balochistan	149,467	19,723	—	—	347,190
NWFP	6,194	16,491	15,160	36,676	74,521
FATA	—	13,580	11,239	2,401	27,220
Total	**409,867**	**115,490**	**43,413**	**49,274**	**796,044**

Source: Aslam, M. 1987. Desertification in Pakistan: Some Visible Effects. In *Proceedings of US-Pakistan Workshop on Arid Lands Development and Desertification Control, Islamabad, January 9-15, 1986,* 163-169. Islamabad: Pakistan Agricultural Research Council.

Barani areas are prone to severe soil erosion limiting agricultural production. The present yields in these areas are very low. These can be reasonably improved through the creation and adoption of improved practices. The rural population of the barani areas, mainly consist of subsistence farmers whose per capita income has been calculated at $37, which is far below the national average (30). The socio-economic conditions of the people inhabiting the arid lands have contributed significantly towards the problem of desertification. They are generally poor, less educated, and have remained isolated from modern technologies and facilities of urban agricultural environments. They also suffer from cultural discrimination which reinforces their isolation and poverty.

In the light of the situation discussed above, it is high time that vigorous efforts for the rational exploitation of the country's natural resources are made, in order to feed the future generations adequately. Saving the land from desertification and converting waste lands into productive farms is a major task. For this purpose, agricultural methods developed in other countries to combat the problem of desertification should be applied here, after adapting them to our own socio-cultural environments. More attention should be given to the biological approach especially to the introduction and establishment of dry-zone crop varieties, capable of higher yields with minimum inputs.

URBANIZATION

Population-wise, Pakistan is the fourth largest nation among the 37 low-income countries, after China, India and Bangladesh. The urban population is increasing at the rate of about 6% per annum against the overall population growth rate of 3.1%. Higher population growth in Pakistan is accompanied by significant internal migration. According to the 1981 census, a total of 5.92 million persons had migrated within the country, with 87.6% moving from rural to urban areas and only 12.4% moving in the reverse direction. Of the rural migrants, slightly more than half settled permanently in the cities. As a result of this high rate of urbanization, the population of urban areas increases by more than one million persons every year. If the existing rate of population growth and urbanization continues, by the year 2000 about one-half of Pakistan's total population will be living in urban areas, compared to about one-fourth in 1970 (25). Table 28 gives the rural-urban population in Pakistan, during the past three decades.

Like other developing countries, Pakistan is suffering from the negative effects of urbanization. It has been unable to take advantage of the potential economic benefits of population density. The existing urbanization rate is frightening considering the problem of how, and where, to accommodate such a large population. The per capita income in the country is low and allows only subsistence living with low consumption and investment levels. Therefore, the resources available for the development of urban infrastructure are meagre. Despite heavy doses of investments, they have failed to keep pace with the needs arising out of the massive rural-urban migration. It may be added here, that resources have sometimes been drawn from rural areas for urban investments. This has aggravated rural poverty, triggering further migration, and adding to the miseries of both the urban and rural areas.

Rural-urban migration has created a number of problems. Pakistan's rural population living in some 43,000 villages is almost totally dependent on the productivity of land. According to the 1981 census, out of 9 million rural households, 6.3 million or 70% were agricultural households, the majority of them being small farmers owning less than 5 hectares of land. A study of such small farmers in the Punjab, revealed that about a fourth of them were unable to meet the basic needs of their families from income from the land, and had to find other means of livelihood. The major factors behind the migration of the rural population are slow progress in the agricultural sector, a steady decline in the per capita cropped area, low crop

TABLE 28

PROPORTION OF RURAL-URBAN POPULATION IN PAKISTAN

	YEAR							
	1961		1972		1981		1990*	
	(million)							
Population								
Total	46.20	(100.00%)	65.31	(100.0%)	84.25	(100.0%)	110.36	(100.0%)
Rural	35.80	(77.48%)	48.72	(74.6%)	60.41	(71.7%)	77.70	(70.4%)
Urban	10.40	(22.52%)	16.59	(25.4%)	23.84	(28.3%)	32.66	(29.6%)
Inter-censal growth rate (per annum)								
Total				3.02%		3.1%		
Rural				2.69%		2.6%		
Urban				4.10%		4.4%		

Source: *Economic Survey 1989-90.*

* Estimated.

yields due to inefficient land and water management practices, failure to absorb unskilled and skilled labour by modern technological systems, lack of other employment opportunities and environmental degradation due to deforestation and desertification.

The process of urbanization has accelerated to such an extent that prime agricultural land is being eaten away at a very fast rate. Lahore and Faisalabad, which had several patches of good agricultural land about 25 years ago, have been left with no arable land within city limits. A case study of Peshawar has revealed that over the past 20 years, the city has lost over 2,700 hectares of agricultural land to urban users (12).

In view of the situation discussed above, there is an urgent need to consider population, resources and development in a unified structure. In a country like Pakistan where population is primarily dependent on agriculture, and the scope for further extension of cultivated area is limited, the increasing pace of urbanization will further aggravate an already limited resource base.

4. FUTURE OUTLOOK

Pakistan is a country known for its fabulous rivers, bewitching mountain valleys and fascinating plains. It also possesses some of the most fertile areas of the world inhabited by very industrious farming communities. But, in spite of this, the standard of living of a vast majority of its population remains at subsistence level. Although the performance of the Pakistani agricultural sector, despite many constraints, has been quite impressive in recent years, it is much below its real potential. Ineffective planning, sloth, traditional modes of production, and vagaries of weather have reduced this country of plenty into a food deficit area. This has necessitated the import of food grains worth millions of rupees annually, putting a severe drain on the national exchequer, which a developing country like Pakistan cannot afford.

Besides this sorry state of affairs, the environment in Pakistan is currently under great stress from a growing human and livestock population.

Forests are being denuded, marginal lands are being cultivated and grasslands are being overgrazed. The uplands suffer from soil erosion while sedimentation and floods afflict downstream areas. Desertification is on the increase, and renewable resources continue to be depleted. The very resource base of production is under threat. The challenge is to make ecological resources more productive, sustainable, and compatible with a healthy environment.

Three challenges confront the scientific community in the agricultural sector if the target for sustainable production is to be met. The first challenge is to sustain past increases in food production, the second is to improve the productivity of cropping and resource systems in underdeveloped environments, and the third is to develop production practices that raise productivity without polluting the environment or creating any other negative impacts in the process.

Keeping in view the detailed discussions presented in the earlier parts of this paper, an effort is being made here to propose a strategy for the sustainable development of agriculture, commensurate with Pakistan's socio-economic conditions and traditional norms.

NATIONAL AGRICULTURE RESEARCH SYSTEM

Agriculture, being the mainstay of the nation's economy, needs immediate attention if it is to be developed sustainably. The agricultural production system in the country can operate on sound scientific lines and on a stable basis only if farm technology is kept in tune with the changing environmental and socio-economic conditions, through an efficient and dynamic agricultural research system. Without the full support of such a system, food production will soon reach a point of stagnation and may start declining thereafter, even with the best of management practices. On the contrary, requirement for agricultural products is bound to increase substantially, with an increase in population, rising income levels and progressive development of agro-industries. Besides high cost-benefit ratios, agricultural research permits a more efficient use of scarce natural resources, facilitates the substitution of less expensive and more abundant resources for more expensive or increasingly scarce resources, and releases constraints on growth imposed by inelastic resource supplies. All of these lead to the elimination of poverty and hunger and ensure economic and political stability.

The research system, however, can work effectively only if it is institutionally linked with the dissemination of information and technology so that the knowledge generated and technology developed is expeditiously and effectively utilized at the farm level through a well-knit extension system.

Development of Trained Manpower

The productivity of research in a country is dependent on the availability of scientific manpower. It should not, therefore, be a surprise that research productivity in Pakistan is much lower than in neighbouring India, primarily because of a lack of trained manpower available to undertake research. Shortage of manpower is particularly acute at the level of programme managers who can provide leadership for planning and implementing environmentally sound and economically viable research projects. Special emphasis should be laid on the development of scientific manpower for agricultural research. Measures should also be taken to recruit outstanding young graduates through rigorous tests and groom them into professionals by providing special training. A system of continuing education should be instituted to regularly up-date the knowledge of research scientists and also to train them in middle and higher level management skills.

SOIL FERTILITY

Pakistan is spending substantial amounts on the production and import of chemical fertilizers. But even with their use, per hectare crop yields are far below their potential level. The data presented in an earlier section shows that only one-fourth to one-third of the known potential has, so far, been realized. It is clear that we shall have to produce and apply increasingly larger quantities of fertilizers in the future if crop yields are to be increased significantly. On the other hand, environmental contamination from chemical fertilizers is a major concern these days, especially losses of nitrogen leading to nitrate toxicity. Techniques are now available whereby nitrogen losses can be minimized. In India, for instance, a technique has been developed for coating urea with neem cake and other plant products, which inhibit the action of nitrifying bacteria, reducing nitrate formation. There is a need to initiate appropriate activity in the country to find out the future prospects of this and other similar techniques.

The possible use of alternate sources of nitrogen for increased crop production has been discussed in the earlier parts of this paper. To some extent the need for plant nutrition can be met by the use of bacteria and other micro-organisms in the soil. Already a number of species have been known to fix atmospheric nitrogen. The potential of such species should be fully exploited through appropriate research and development efforts. Attempts should also be made to identify this characteristic in other commercial species. Use of organic matter and other biofertilizers should be encouraged for increased fertilizer efficiency. Efforts need to be intensified to find an indigenous agro-mineral and develop its production. The price of such an agro-mineral should be kept within the reach of a resource-poor farmer. The development of such an industry will not only decrease the reliance of the agricultural sector on chemical fertilizers, but will also create employment opportunities. Besides all these innovations, there is a need to educate farmers about applying fertilizers according to soil and crop needs. Efficient technical services to help farmers determine these needs, should be provided.

CROP PROTECTION

Lower yields in many crops, including oilseeds and pulses, are partly due to the farmers' inability to effectively adopt pest control measures. Most countries in the world make large-scale use of pesticides. But the overuse and misuse of pesticides has given rise to serious problems which include increased resistance in pests, the persistence of toxic residues in soils and ecosystems, and a variety of hazards to field applicators, food consumers and others who may come into contact with pesticides.

Recent research in Pakistan, as well as in other countries, has shown the possibility of controlling pests through an integrated approach in which the use of pesticides is only one component of control. Other components include:

- Greater reliance on resistant varieties.
- Making agronomic adjustments to avoid insect population build up.
- Biological control through release of selected parasites in the fields.
- Monitoring of insect build up in the field, and use of pesticides only when the insect population reaches a critical level.
- Introduction of intercropping rather than monoculture agriculture.

These are some of the new directions of research which are likely to provide solutions to the problems of higher production, with increased efficiency of the production process, while maintaining the quality of the environment.

IRRIGATION MANAGEMENT AND LAND DRAINAGE

The development of the irrigation system has been associated in many ways with the serious problems of soil salinity, soil erosion and waterlogging. These problems cause heavy losses in parts of the CCA. Water management in the irrigated areas is of tremendous importance. It must be aimed at meeting the present and projected demands for increased food production. Irrigation water management besides aiming at a judicious use of this scarce resource must also take into account maintenance of appropriate subsoil water-levels and a favourable salt balance in the soil. The following steps are necessary to control faulty irrigation systems and to improve the soil-plant-water relationship:

- Efficient delivery system to minimize water losses in canals, distributaries and water-courses. These losses include seepage, over-spills, leakage, etc.
- Efficient irrigation application system to minimize water losses due to over-irrigation and uneven application on unlevelled fields.
- Scheduling of irrigation to optimize crop production under given water availability and reducing deep percolation by avoiding over-irrigation.
- Use of efficient and improved non-water inputs and cultural practices to increase water use efficiency in terms of marketable products.
- Development and introduction of water harvesting and moisture conservation techniques in rain-fed areas.

ENERGY

Modern agriculture is becoming increasingly dependent on energy. Keeping in view the existing energy situation in the country, it is imperative to look for new horizons for efficient production of energy, particularly from renewable resources. In this regard the following strategies are suggested:

- Studies on tree-crop interface should be encouraged. Trees on farmlands will provide both timber and fuelwood to the rural community. Adequate supply of fuelwood will help save burning of cow dung, which is a vital source of plant nutrition.
- Biogas generation plants should be introduced extensively in rural areas. The design of these plants should be such that it would be easy to construct, and it should be suitable for prevailing conditions at the specific location of their use.
- Since agricultural wastes/residues are valuable biofuels, technology to efficiently use this resource for energy production should be introduced.
- Plants, such as gauyule and euphorbia should be introduced in arid tracts. They, along with algae, are a very promising source of hydrocarbon which can be used to generate energy.

LIVESTOCK DEVELOPMENT

The livestock sector plays an important role in the country's economy and provides a protein-rich diet to the entire population. For sustained development of this sector, particularly in relation to agriculture, the following measures are suggested:

- Silvo-pastoral studies should be initiated to find a solution to the problem of fodder shortage for livestock. For this purpose improved varieties of grasses and legumes along with fodder trees and shrubs should be planted on marginal lands. These silvo-pastoral areas in addition to providing nutritious feed for livestock, will reduce soil erosion. Moreover, side-prunings of trees and shrubs will be an important source of fuelwood.
- Pastures should be established on sufficiently large areas in different ecological zones of the country, and these should be seeded with selected forage species. People should be encouraged to graze their livestock under well designed grazing systems on nominal charges.
- The private sector should be encouraged to establish pastures and ranches.
- Salt-resistant fodder crops should be identified and planted on saline soils to tap the potential of these neglected areas.

WOOD PRODUCTION AND DESERTIFICATION

The country faces an acute shortage of forest resources for timber and fuelwood, as well as forest cover for ecological stability. The situation can be improved by involving the farming community in tree plantation. Agro-forestry is gaining tremendous importance worldwide as a means of bringing more area under tree cover, not only to meet the increasing needs of wood and wood products, but also to increase farm income and to create a healthy environment for human beings. In Pakistan, agro-forestry has great potential. The following measures are needed to make agro-forestry popular among farmers.

- Involvement of non-government organizations, or formation of co-operative societies to motivate the farming community to adopt agro-forestry practices.
- Providing incentives to farmers to plant trees on their lands by giving a rebate on water and land changes.
- Developing a network of standard nurseries at suitable places throughout the country, to provide planting stock at nominal prices, for planting on farmland.
- Creating appropriate marketing facilities for the sale of wood from farmlands. Alternatively, the government may purchase whole woodlots from the farmer and make payment at the site according to the prevailing market prices as is being done for certain agricultural products.
- Agro-forestry should be included in the curricula of schools and colleges at different levels. Special cells in the existing Departments of Forestry and Agriculture should be created with the sole responsibility of educating the public on agro-forestry.
- The media vis-a-vis television, radio and the press, should be utilized in an effective manner to popularize agro-forestry.
- Research organizations like the Pakistan Agricultural Research Council and the Pakistan Forest Institute should be strengthened further in order to provide additional services in this discipline. Literature relevant to this field should be obtained from all available sources for the guidance of research and development personnel.

Desertification control is another area which requires immediate attention. Although several agencies in the country are fighting against this menace, there is an urgent need for a national level campaign to tackle this problem. The following suggestions are made for this purpose:

- As recommended by the National Commission on Agriculture, a separate agency the Watershed and Arid Land Development Authority (WALDA) be established to evolve a long range policy for conserving arid land resources.
- Irrigation water management techniques be improved to minimize the hazards of waterlogging and salinity.
- The ability of trees to restore eroded land back to its pre-eroded state is well documented. Therefore, tree establishment programmes in areas vulnerable to severe water and wind erosion be taken up immediately.
- Information on practices successfully adopted in other countries against desertification should be gathered, and the possibilities of their application under local conditions should be examined.
- A strong collaboration should be developed with the United Nation's Environmental Programme (UNEP) to benefit from their database on desertification.

REFERENCES

1. Amjad, M., and N. Khan. 1990. *The State of Forestry in Pakistan (1989)* Peshawar: Pakistan Forest Institute.

2. Anon. 1982. *Energy and its Development*. Islamabad: Pakistan Academy of Sciences.

3. Anon. 1985. The Biocides. *Pakistan Agriculture* 8, no. 5: 3-5.

4. Ashraf, M. M. 1987. Role of Forestry in Watershed Management. *Pakistan Journal of Forestry* 37, no. 4: 197-202.

5. Aslam, M. 1987. Desertification in Pakistan: Some Visible Effects. In *Proceedings of US-Pakistan Workshop on Arid Lands Development and Desertification Control, Islamabad, January 9-15, 1986,* 163-169. Islamabad: Pakistan Agricultural Research Council.

6. Baig, M. M. H., and S. Akhtar. 1983. Pesticides and their Degradation Through Micro-organisms. *Progressive Farming* 3, no. 3: 36-37.

7. Brown, L. R., and J. L. Jacobson. 1986. *Our Demographically Divided World* Worldwatch Paper no. 74 (December). Washington, D.C.: Worldwatch Institute. p. 54.

8. Dover, M., and M. T. Lee. 1987. *Agro-Ecology for Sustainable Development to Feed the Earth*. New York: World Resources Institute. pp. 42-50.

9. Durrani, N. U. 1987. Let Livestock Production be Export Oriented. *Pakistan Agriculture* 9, no. 7:10-15.

10. Economic Advisor's Wing, Finance Division. 1990. *Economic Survey 1989-90.* Islamabad: Government of Pakistan.

11. Environment and Urban Affairs Division-Government of Pakistan, Canadian International Development Agency and the International Union for the Conservation of Nature and Natural Resources. 1986. *Towards a National Conservation Strategy for Pakistan, Proceedings of the Pakistan Workshop, August 1986*. Islamabad: E&UAD-GOP, CIDA and IUCN.

12. Environment and Urban Affairs Division.

1987. *Environmental Profile of Pakistan.* Islamabad: Government of Pakistan. p. 289.

13. Gaur, A. C. 1983. Micro-organisms and Their Service to Agriculture and Environment. *Indian Farming* 33, no. 3: 20-23.

14. Jain, J. K. 1983. Agriculture and Environment. *Indian Farming* 33, no. 3:5-9.

15. Khan A. G., R. S. Afridi, and Y. M. Memon. 1988. *Dryland Agriculture in Pakistan*. Paper presented at the Seminar on Dryland Agriculture, June 20-24, Ankara, Turkey.

16. Khan, C. M. A, and R. Roohi. 1984. Energy Plantation and Foliage Chemicals - A Review. *Progressive Farming* 4, no. 3: 11-17.

17. Khan, C. M. A., and N. Mohammad. 1987. Rangelands in Pakistan. In *Proceedings of US-Pakistan Workshop on Arid Lands Development and Desertification Control, Islamabad, January, 9-15, 1986*, 13-22. Islamabad: Pakistan Agricultural Research Council.

18. Khan, S. R. A. 1987. Dryland Agriculture in Pakistan. In *Proceedings of US-Pakistan Workshop on Arid Lands Development and Desertification Control, Islamabad, January 9-15, 1986*, 29-35. Islamabad: Pakistan Agricultural Research Council.

19. Khosoo, T. N. 1983. Energy from Biomass. *Indian Farming* 33, no. 3: 10-13.

20. MacNeil, J. 1988. *Our Common Future: Sustainable Development and CGIAR*

21. Mahmood, A. N.d. *Energy: A Pakistan National Conservation Strategy Sector Paper.* Report for IUCN-The World Conservation Union, Pakistan, Karachi.

22. Malik, M. T. 1988. Pesticides: To Spray Or Not To Spray. *Economic Review* 19, no. 6: 33-34.

23. Mann, R. A., and M. Ashraf. 1985. Green Manuring in Different Cropping Systems. *Progressive Farming* 5, no. 5: 11-13.

24. McGaughey, S. E. 1988. *The Role of Multilateral Agencies in Promoting Sustainable Development*, 29. Paper delivered at the Conference on Environment, Culture, and Sustainable Development, University of Minnesota.

25. Mir, S. H. 1987. Development Planning and its Environmental Implications in Pakistan. In *Proceedings of the National Seminar on Environmental Management for Sustainable Socio-Economic Development, January 25-29, Lahore, Pakistan*, 113-121. Bangkok: Economic and Social Commission for the Asia-Pacific.

26. Mohammad, N. 1988. *Rangeland Management in Pakistan*. Kathmandu: International Centre for Integrated Mountain Development.

27. Mohammad, N., and M. S. Naz., M. 1985. Range Management and Forage Research in Pakistan. *Progressive Farming* 5, no. 5: 44-51.

28. Mufti, A., P. Akhtar, I. A. Qazi, and S. Z. I. Zaidi. 1986. Country Paper on Pakistan. In *SAARC Workshop on Renewable Energy Resources, 8-10 April,* 73-87. Islamabad: Ministry of Science and Technology.

29. National Commission on Agriculture, Ministry of Food and Agriculture. 1988. *Report of the National Commission on Agriculture*. Islamabad: Government of Pakistan.

30. Pakistan Agriculture Research Council. 1983. *Barani (Rain-fed) Agricultural*

Research and Development Project. Islamabad: PARC.

31. Sandhu, G. R. 1988. Present and Future Prospects of Bio and Organic Fertilizer Use: Country Report, Pakistan. Paper presented at Expert Consultation on Asian Network on Bio and Organic Fertilizers, 6-9 September, Bangkok, Thailand.

32. Sandhu, G. R., and R. H. Qureshi. 1986. *Salt-affected Soils of Pakistan and their Utilization. Reclamation and Revegetation Research*. Amsterdam: Elsevier Science Publishers B. V. pp. 105-113.

33. Shah, A. A. 1987. State of Environment in Pakistan. In *Proceedings of National Seminar on Environmental Management for Sustainable Socio-Economic Development, January 25-29, Lahore, Pakistan,* 91-4. Bangkok: Economic and Social Commission for the Asia-Pacific.

34. Shah, F. H. 1988. Food and Feed Contaminants. *Proceedings of the Pakistan Academy of Sciences* 225, no.1: 9-24.

35. Shah, S.L. 1981. Ecological Degradation and Future of Agriculture in the Himalayas. *Indian Journal of Agricultural Economics* 37 no. 1: 1-22.

36. Sheikh, M. I., and M. Amjad. 1985. Creation of New Resources for Fuelwood and Wood Energy. *Progressive Farming* 5, no. 5: 19-26.

37. Statistics Division, Federal Bureau of Statistics. N.d. *Survey of Self Generating Electricity Undertakings 1985-86*. Islamabad: Government of Pakistan. p. 12.

38. Swaminathon, M. S. 1987. *Agro-Forestry in Asia. The Promise of Agro-forestry for Ecological and Nutritional Security, The Potential of Agro-forestry*. Nairobi: International Centre for Research in Agro-Forestry. pp. 19-41.

39. Zafar-Uddin. 1985. Constraints and Strategy for Development of Rangelands in Pakistan. *Pakistan Agriculture* 7, no. 11: 20-3.

40. Zafar-Uddin, and A. Amin. 1982. Role of Trees in Boosting Agriculture. *Progressive Farming* 2, no. 4: 5-9.