Development of Dryland farming in various regions

Dryland farming is practised in various parts of the world. The specific practices vary because of differences in local conditions, both physical and social. Development histories of some of the larger dryland regions of the world are presented below.

AUSTRALIA

Much of Australia's agricultural income comes from the production of food and fibre on dryland farms (Squires, 1991). In Australia, dryland-farming systems combine crops, pastures and fallow periods for the purpose of making efficient use of the limited water. Moisture is usually the deciding factor in the success of cereal cropping. Fallowing can be an important strategy to store and conserve water for the establishment and maturation of the crop. Winter crop production often depends on fallowing over the summer.

Australian dryland-farming systems have distinctive characteristics (Tow, 1991). These reflect: the importance of livestock products, particularly sheep, and wheat as export commodities; the availability of pasture legumes for incorporation into crop rotations; and the need for efficiency imposed by farm size. However, in general, Australian dryland-farming systems have similarities to three major world farming systems: Mediterranean agriculture; mixed farming of Western Europe and eastern North America; and large-scale grain production.

Mediterranean agriculture has had a large influence on the agriculture of southern Australia because the of the Mediterranean-type climate and because of the importance of crop, pasture, weed and livestock species from the Mediterranean basin. Mixed farming areas of the United States of America featuring large farm size and dependence on mechanization are similar to Australian cereal producing farms (Tow, 1991). One similarity is the initial abundant supply of new fertile land and the relative scarcity of labour. Large-scale cereal production is common in parts of Argentina, Australia, Canada, the former Soviet Union and the United States of America, and their early successes came mainly through the exploitation of large areas of initially fertile lands brought under cultivation. Australian examples are the black, grey and brown clays (mainly Vertisols) of northern New South Wales and southern and central Queensland. Because of the initial high fertility, inputs of fertilizers were low for many years. However, these systems were not sustainable because of the lack of flexibility, risk of soil erosion, buildup of disease organisms, and periodic low prices (Tow, 1991). Australian farmers have had some success in finding alternative crop and pasture species and in overcoming erosion problems by maintaining crop residues on the soil surface through conservation tillage (Tow and Schultz, 1991; Cornish and Pratley, 1991).

CHINA

Arid and semi-arid lands in China cover 52 percent of the country – 31 and 21 percent, respectively (Li Shengxiu and Xiao Ling, 1992). These lands are located between 30 and 50

°N, from the warm temperate belt in the south to the temperate zone in the north. Rainfall is very variable; annual totals average 300–500 mm, and increase gradually from northwest to southeast. Rainfall from June to September accounts for 70–80 percent of the annual total.

Li Shengxiu and Xiao Ling (1992) extensively reviewed the extent, characteristics, and management of the drylands in China. Management has focused on transforming desert and desertified lands, controlling erosion, and making efficient use of the precipitation. Although the drylands make up more than half of the land area, they account for 30 percent of the arable land. The development of agriculture in these vast areas is extremely important to the nation.

The basic tillage principle for conserving soil and water in China is to increase soil-surface roughness (Li Shengxiu and Xiao Ling, 1992). This is done mainly by building low earthen banks between fields, making ridges and furrows, or digging ditches in fields. Examples include: contour ploughing, contour planting, digging pits for seeding, contour plough furrows, and cultivation in pits or furrows. Another important principle used in designing soil- and water-conserving cropping systems is to increase plant cover. Narrow crop rows, intercropping and interplanting are widely used for this purpose. These practices increase the density of the crop canopy, which reduces raindrop impact on the soil surface and surface sealing, maintains soil permeability, and reduces or eliminates runoff and erosion.

Fallowing has also been considered an important practice for restoring soil water and fertility in China. During the fallow period, weeds are controlled by cultivation. The fallow period differs depending on precipitation and soil fertility. The effect of a one-year fallow period on the subsequent crop production will last for at least 3 years.

Ploughing to a depth of about 20–30 cm has been used widely in dryland farming as an effective method for storing precipitation. Deep ploughing is generally carried out in the summer, but not in the spring. Summer ploughing keeps the soil loose during the rainy season of July–September, enhances water penetration, and reduces runoff. Spring ploughing increases water loss from the soil because this season is often dry (Li Shengxiu and Xiao Ling, 1992).

As in India, dust mulching is commonly used in China for conserving soil water, and research has shown it to be beneficial (Xi Chengfan, 1961). This practice is discouraged in North America. Stubble mulching has been important for controlling wind erosion on dryland fields in the United States of America following the Dust Bowl. It is a minimum tillage practice that aims to leave substantial amounts of crop residues on the soil surface to reduce evaporation. A study of this practice in China (Han Siming, Si Juntung and Yang Chunfeng, 1988) showed that water conservation from this practice was poor and that mulching after sowing was unfavourable to wheat. Wheat seedlings often became yellow and had more sharp and dry leaves when fertilizers were not applied. There was also a shortage of crop residues and this hampered crop residue management on the soil surface. Another major problem was the low soil temperature that had negative effects on the mineralization of soil nutrients and enhanced weed growth and plant diseases.

The use of plastic mulches in China has expanded rapidly. Ma Shijun (1988) reported that there were more than 1.3 million ha of plastic mulch in use, mainly in the northern provinces of Liaoning, Shanxi, Shaanxi and Shandong, and in the Xinjiang Autonomous Region. Plastic-film mulch was used on about half of the cotton and peanut fields and accounted for more than three-quarters of the fields using plastic mulch in 1985. The use of plastic mulches in China has continued to increase at a rapid rate. However, the driving factor for this practice has been the desire to increase soil temperature rather than reduce soil-water evaporation.

ETHIOPIA

Ethiopia is facing a tremendous challenge in meeting the food needs of a rapidly growing population. Famines have occurred frequently in Ethiopia, with the 1984–85 famine affecting almost ten million people (Hurni, 1993). Both irrigated and dryland cropping areas will have to be developed or improved in the future. These tasks will not be easy, inexpensive or swift.

There were 194 000 ha of irrigated land in Ethiopia in 1994, representing about 3.2 percent of the cultivated area (FAO, 1995). Ancient irrigation systems have a long history in Ethiopia, with modern systems dating from the 1960s. The first large irrigated farms, established by private investors, were located in the middle Awash Valley, where there are large sugar estates, and fruit and cotton farms. These farms became the responsibility of the Ministry of State Farms with the 1975 rural land proclamation. There are small-scale, medium-scale and large-scale irrigation systems in Ethiopia (FAO, 1995). Small-scale projects are smallholder projects for a single peasant association up to 200 ha in size. Medium-scale systems are between 200 and 3 000 ha, extending beyond one peasant association. Large-scale systems are centrally managed state farms for commercial production and cover 3 000 ha or more.

In 1988, the costs of developing large-scale schemes were US$18 000–25 000/ha, without including water storage. Development costs of medium-scale schemes were US$10 000–15 000/ha, and those of small-scale schemes were US$2 300–3 400/ha. These costs are prohibitive in most cases and largely explain why the irrigated area in Ethiopia is less than 8 percent of the land considered potentially irrigable (FAO, 1995).

The development of sustainable dryland systems in Ethiopia is also challenging. Seventy percent of the people live in the mountainous areas, where 60 percent of the land has slopes greater than 16 percent (FAO, 1995). Annual soil losses can reach 300 tonnes/ha. Therefore, soil- and water-management practices that will sustain crop production over the long term will also be costly, but considerably less so than the development of irrigated land. The potential for water harvesting is also great because of the sloping lands and high-intensity precipitation events that result in large amounts of runoff.

INDIA

Dryland farming in India began centuries earlier than in North America. However, there are some striking similarities between the two regions with respect to the scientific study of dryland farming. Hegde (1995) reported that, in 1917, Aiyer had listed the important farmer practices and found them quite similar to those that Campbell (1907) had proposed for the Great Plains in the United States of America in the early 1900s. Field bunding, fall ploughing, frequent intercultivations, drill sowing, and growing drought-resistant crops, such as finger millet, grain sorghum and pearl millet, were some of the practices listed.

Scientific study of dryland farming was initiated by the Government of India in 1923. Early research focused on improving crop yields. Important practices included: (i) bunding to conserve soil and water; (ii) deep ploughing once in three years for better intake and storage of water; (iii) use of farmyard manure to supply plant nutrients; (iv) use of a low seeding rate; and (v) intercultivation for weed and evaporation control. These practices gave a 15–20 percent increase over the base yields (Hegde, 1995, Singh, 1995). By the mid-1950s, the emphasis had shifted to soil management. Soil conservation research and training centres were established at eight locations, focusing on contour bunding. However, negative results were often obtained because of water accumulation and runoff problems, particularly on Vertisols. Even where yield increases were observed, they were again not more than 15–20 percent above the base yields.

The importance of shorter-duration crops to match the soil-water availability period was recognized in the 1960s. It was also in the mid-1960s that high-yielding hybrids and cultivars became available that were responsive not only to fertilizers but also to management. An All-India Coordinated Research Project for Dryland Agriculture was established, and the research emphasis shifted to a multidisciplinary approach to tackle the problems. Similar efforts were initiated at the International Crops Research Institute for the Semi-Arid Tropics at Hyderabad in 1972.

Although many of the recommended practices for dryland farming in India are similar to those for North America, there are differences. A highly recommended practice for water conservation in India is the use of dust mulch (Hegde, 1995), similar to that recommended in the North America in the early 1900s, which is commonly considered to have contributed to the Dust Bowl. These contrasting recommendations illustrate the importance of recognizing and addressing the differences between semi-arid regions. Semi-arid conditions in North America are very different from those in India. For example, summer fallow has played an important role in North America because some precipitation occurs throughout the year, but at no time does monthly precipitation exceed PET. Many dryland regions in the Great Plains in the United States of America do not have any month with precipitation that even reaches half of PET. In contrast, most dryland areas in India have more than seven months with essentially zero precipitation. They then have a monsoon season of varying length when the precipitation greatly exceeds the potential evapotranspiration for at least a portion of the growing season. Therefore, fallow for storing soil water is not a viable alternative because much of the water saved during the rainy season would be lost during the prolonged dry period. More importantly, there is usually more than enough precipitation during the monsoon season to fully wet the soil profile.

MEDITERRANEAN REGIONS

A Mediterranean-type climate is characterized by the concentration of rainfall in the winter half-year – from November to April in the northern hemisphere, and from May to October in the southern – with drought in summer. In California (the United States of America) and in Chile in particular, winter rainfall may constitute 80–90 percent of the annual precipitation, but this is less common in the Mediterranean basin itself. A winter precipitation exceeding 65 percent of the annual total has been used to define the climate zone. The worldwide distribution of Mediterranean climates is between latitudes 32 and 40 ° north and south of the equator on the west coasts of the continents (Boyce, Tow and Koocheki, 1991). North of the Mediterranean Sea, they extend into higher latitudes and in western Australia into lower latitudes. Major dryland-farming areas with a Mediterranean-type climate are located in Morocco, Algeria, Tunisia, the Libyan Arab Jamahiriya, Syrian Arab Republic, Jordan, Iraq, Turkey, the Islamic Republic of Iran, Chile, Australia, and parts of California and the

Pacific northwest of the United States of America. Annual precipitation values suitable for agriculture are generally considered to be from 250 to 500 mm. Most areas show a wide fluctuation in: total precipitation from year to year; distribution during the season; time of onset of the rainy season; duration of the rainy season; and intensity of rainfall during precipitation events. Except for Australia, where the topography is moderately flat, countries with Mediterranean-type climates are characterized by rugged mountain ranges. Increasing elevation correlates positively and strongly with increasing precipitation. Dryland agriculture has been practised in some of these areas for perhaps 10 000 years or more (Boyce, Tow and Koocheki, 1991).

The West Asia – North Africa region constitutes a large part of the dryland farming areas of the Mediterranean regions. There are two major types of dryland-farming systems in these areas: the wheat-based systems in wetter areas; and the barley-based systems in drier areas. Although there are some variations owing to elevation, soil depth and soil type, the transition between the two systems is generally considered to be the 300 mm isohyet (Boyce, Tow and Koocheki, 1991). Yields are often low as a consequence of low soil fertility, exacerbated by erosion. Fallow is also common in these areas, but it is practised very differently from in other major dryland cereal-cropping areas. Fallows are generally uncultivated weedy fallows. The fallow fields are grazed by animals, with a primary purpose of increasing soil fertility rather than conserving soil water. The main goal of the barley-based farming systems is animal production. Reliance on animals increases with decreasing amount and reliability of rainfall. Animal production in these low-rainfall areas, as in other dryland regions of the world, is an important survival mechanism in subsistence-type agriculture where the risk of crop failure from inadequate rainfall is high.

Farming systems in these regions continue to evolve depending on a variety of pressures, particularly those related to increasing population, increasing shortage of land, increasing mechanization, changing market forces, and a variety of social and political factors (Boyce, Tow and Koocheki, 1991). In the higher-rainfall wheat-based areas, crop production will probably continue to dominate although there is increasing tree-fruit production. In the lower-rainfall wheat-based systems and the barley-based systems, animal production is assuming greater importance. Barley is replacing both wheat and fallow to satisfy the increasing need for animal-feed production.

Although animal production is increasing, Boyce, Tow and Koocheki (1991) state that an important feature of all of the farming systems is that cropping- and livestock-production systems are not generally integrated. Cropland is predominantly owned and worked by farmers who do not own livestock, while livestock owners do not usually crop the land. This has been the general pattern for centuries or millennia in most of the cropped areas of the Mediterranean basin. This presents both a physical and a social barrier to the use of systems that efficiently integrate cropping and livestock production under one management system, such as the Australian ley farming system.

The cropping systems in the other Mediterranean-type climate regions – Chile, Australia, and parts of California and the Pacific northwest in the United States of America – usually include cereal production as an important component (Boyce, Tow and Koocheki, 1991). However, the mix of crop and farm animals is somewhat different. The degree of industrialization accounts for many of the differences between the farming systems. Broadly speaking, the higher the national income per capita is, so the more intensive and specialized the farming patterns are.

NORTH AMERICA

The Prairies in Canada and the Great Plains, Pacific northwest, parts of the southwest and intermountain areas in the United States of America constitute the major dryland-farming areas of North America. These areas are major contributors to the food and fibre production system. Gras (1946) suggested that, historically, six general types of farming developed in the United States of America. Listed in chronological order, they were: woodland, prairie, ranch, irrigated, dryland, and leftover farming. This is a natural progression that is typical of other regions in the world in that agriculture expands to increasingly marginal lands. In the United States of America, as settlers pushed west from the sub-humid eastern edge of the Great Plains, they found that crop production became more erratic and precarious.

Early-day conservationists warned of the erosion that would take place in many parts of the Great Plains if the grass cover on the land were destroyed by cultivation. However, high wheat prices following the First World War, coupled with the development of power machinery, led to the rapid expansion of cultivated land and large-scale production of wheat and other crops. This expansion in cultivated land took place primarily between 1915 and 1925, but dryland farming had become well established in the early 1900s. One of the early promoters of dryland farming was Campbell (1907), who published a manual of recommended practices that were widely followed. Campbell believed erroneously that a “dust mulch” on the surface not only conserved substantial amounts of soil water but also attracted it from the atmosphere. There was above-average precipitation during the first 30 years of settlement in the Great Plains when these practices were being advocated, and little damage was noticed. Another factor that led to expansion was that the United States Department of Agriculture (USDA) was formed in 1862 and provided a basis for scientific study. This later led to development of a series of dryland experiment stations throughout the Great Plains, some as early as 1903. In 1914, the USDA Division of Dryland Agriculture was established, consisting of 22 field stations to study crop adaptation and cultural practices (map in Burnett, Stewart and Black, 1985). Although a few of these stations remain today as part of the USDA Agricultural Research Service and a few others as units of the Agricultural Experiment Stations of various states, the Division of Dryland Agriculture was terminated in 1938.

After the unusually wet conditions in the Great Plains during the early years of development, a major drought in the 1930s led to severe wind erosion. All of the Great Plains and the Canadian provinces were affected but the worst-hit areas were in southeast Colorado, southwest Kansas, western Oklahoma and northwest Texas, resulting in the infamous Dust Bowl. Surveys made shortly after the drought years of the 1930s in the southern Great Plains wind-erosion area suggested that 43 percent of the area had serious wind erosion damage (Joel, 1937). Finnell (1948a) estimated that about 2.6 million ha in the southern Great Plains were removed from cultivation and remained idle or were returned to grass because erosion had made them unproductive, but that about 10.3 million ha of less erodible soils survived the drought cycle without significant erosion damage and were put back into cultivation in the 1940s. Finnell (1948b) pointed out that 59 percent of the serious erosion had occurred on poorer lands that probably should never have been cultivated. This reinforces the point made by Mathews and Cole (1938) about deciding whether or not particular lands in semi-arid areas should be cultivated.

As already discussed, summer fallow was an important practice in the development of dryland farming in North America. Fallow continues to be an important component of many cropping systems. However, its length has been shortened and the use of crop residues as surface mulches has been found very beneficial in increasing the proportion of precipitation stored in the soil profile for subsequent crops. Conservation tillage and no-tillage systems have proved extremely important for water conservation and protection against wind erosion.

WEST AFRICA

Sub-Sahelian West Africa lies between 10 and 14 °N of the equator and is largely semi-arid, with 300–800 mm annual rainfall. Soils are mostly Yermosols (Aridisols), Cambisols (Inceptisols) and Luvisols (Alfisols) (Lal, 1993). These soils are highly susceptible to wind and water erosion. Estimates of annual soil loss range from 10 to 50 tonnes/ha for wind alone. Much of the dryland farming in West Africa occurs in the sub-Sahelian region. Rains tend to be intense and erratic, droughts are frequent and may persist for several consecutive years. The erratic character of the rains makes dryland cropping very unreliable despite relatively high rainfall during parts of the year. Sorghum and millet are the principal crops in the African summer rainfall zones (Dregne, 1982). Dregne also reported that the dominant soil problems in the sub-Sahelian region are low inherent soil fertility caused by coarse textures, soil acidity, low nutrient holding capacity, and high phosphorus fixation. Other important problems relate to surface sealing as well as compaction and hardening to a depth of several centimetres. Lal (1993) reported that cultivation and accelerated soil erosion leads to a rapid loss of soil organic matter and plant-nutrient reserves, which results in a serious decline in soil productivity.

Several traditional techniques are used to increase water-use efficiency in West Africa. For example, the zai system in Burkina Faso and Mali consists of small pits, about 10 cm deep and 10–30 cm in diameter, at intervals of about 1 m. After mixing in some manure and dead weeds, seeds are planted in the pits at the start of the cropping season. Zai are often combined with contour bunds to capture still more of the rainfall for infiltration into the pits.

Pieri (1995) summarized long-term experiments in semi-arid francophone Africa and concluded that continuous cropping without any fallow period is technically achievable while increasing yields. However, annual application of mineral fertilizer with periodic liming is required. A combination of mineral fertilizer, periodic liming, and periodic application of cattle manure brings several benefits, including higher and more-stable yields. Yield stability is particularly improved where water-harvesting techniques are used in combination with fertilizer applications.