Sustainability in Armenia: New Challenges for the Agricultural Sector

Vardan Haykazyan[1] and Jules Pretty[2]

[1]Armenian State Agrarian University (Yerevan, Armenia) and
[2]University of Essex (Colchester, UK)

Centre for Environment and Society Occasional Paper 2006-1,
University of Essex, Colchester UK

Sustainability in Armenia:
New Challenges for the Agricultural Sector

Vardan Haykazyan[1] and Jules Pretty[2]

[1]Armenian State Agrarian University (Yerevan, Armenia) and [2]Department of Biological Sciences, University of Essex (Colchester, UK)

Centre for Environment and Society Occasional Paper 2006-1, University of Essex

Contents

1. Background to Armenian Agriculture
- **1.1 Location and Resources**
- **1. 2 Science and Education**
- **1.3 Industry**
- **1. 4 Agriculture**
- **1.5 Biodiversity Conservation Programmes in Armenia**
- **1.6 Water Resources**
- **1.7 Soil salinity**
- **1.8 Key Problems and Trends**

2. Principles for Agricultural Sustainability
- **2.1 The Wider Challenge**
- **2.2 The Development of Ideas about Sustainability**
- **2.3 Agricultural Sustainability**
- **2.4 Technologies for Sustainability**
- **2.5 Some Opportunities for Improvement**

3. Policy Recommendations
- **3.1 Recent Policy Progress Across the World**
- **3.2 The Need for a Multi-Track Approach**
- **3.3 Policy Priorities for Armenia**

References

Annex A: Profile of Mera Eco 99 Farm
Annex B: Green Manures and Agroforestry
Annex C: Social Capital

Acknowledgements

The authors are very grateful for the kind support for the research for this paper provided by a grant from NATO in Brussels (#EST-CLG-979861).

1. Background to Armenian Agriculture

1.1 Location and Resources

Armenia is in the eastern part of the Armenian Plateau bounded in the north by the Republic of Georgia, east by the Azerbaijan Republic, south by Islamic Republic of Iran, and west by Turkey. Armenia is the most mountainous of the Transcaucasian republics, with an average elevation of 1,800 metres above sea level. Forests and woodlands cover less than a tenth of Armenia, arid land nearly a half, and one-seventh is pasture. Only 10% of the country lies below 1,000m, and its highest point is the 4, 090 m Mt Aragats. The Araks River forms most of Armenia's border with Iran and part of the border with Turkey. The country has an area of some 30,000 sq km, and a population of 3.0 million. The Republic of Armenia was formed on September 21st 1991.

Armenia has one of the oldest indigenous cultures. The name Armenia appears for the first time in history in 521 BC. In 301 AD Armenia became the first country in the world to adopt Christianity as the state religion. The predominant culture in Armenia became Christian and this characterizes the nation today. In 2001 Armenia celebrated the 1,700 years of Christianity. The Armenian language (e-Haieren) is an independent branch of the Indo-European group. The decisive role in preserving the national identity and culture of the Armenian people was played by the Armenian alphabet invented by Mesrop Mashtotz in 396 AD. This alphabet has undergone virtually no alteration in form or structure since its creation.

Armenia is often called an open-air geological, archaeological and architectural museum. In the countryside of Armenia, there are more than 40,000 ancient churches and monuments. Yerevan (782 BC) is one of the oldest continuously inhabited settlements in the world, and has more than 20 museums. One of them, the Matendadaran, preserves more than 12,000 ancient Armenian texts and illuminated, hand-written books and manuscripts from the 9th century onwards.

The Armenians since the Middle Ages have been in large measure a diaspora people. Today, there are some 8 million Armenians across the world. The New Year is the largest holiday of the year, where people exchange gifts and houses are opened to walk-in guests. An annual autumn festival, called Voski Ashun (Golden Autumn), with concerts, traditional dancing and music in October, and the cultural season begins in Yerevan with the harvest and the approach of winter.

The largest Armenian lake, Lake Sevan (50 km northeast of Yerevan), is also the largest lake in Transcaucasian region. The lake lies 1,900m above sea level, and used to cover 1,360 km^2. Unfortunately, over one third of the lake, the country's only fresh water reservoir, has been drained for hydropower, thus threatening water supplies. It has shrunk by 420 km^2 since the Razdan River (the only outflood of the lake) was tapped for hydroelectricity and irrigation. The hill resorts of Jermuk, Bjni, Arzni and Dilizhan are the sources of Armenia's excellent mineral water. Armenia held control of one of three principal branches of Great Silk Road that ran along the Ararat Valley through the territory of modern Armenia. Armenia was first declared a republic in 1918. In 1920, the Bolsheviks then occupied the Republic of Armenia, and the Soviet constitution of 1936 made Armenia one of the union republics of the USSR. Only in 1989, after the collapse of USSR, was independence of the Republic of Armenia proclaimed.

Of the 29,800 km^2 of area, less then half (47%) is suitable for agriculture. Most land ranges from 1,000 to 2,500 m above sea level, with 65% of which on steep slopes (6^o and more inclination), and 90% of the total area has an altitude of more than 1000 m above sea level. Of the 1,392,000 hectares suitable for agriculture, 520,000 ha (37%) is arable land, about 40,000 (2.9%) is perennial plantation, 143,000 (10.3%) is grassland and 689,000 (49.5%) are pasture. Only about 200,000 hectares of agricultural land is irrigated.

The agricultural soils differ across the main agricultural zones. In high areas with altitudes of 1000 to 2000 metres, soils are carbonate, chestnut type or varities of chernozem, with good water-holding capacities. The first two are more shallow and stony, with a low organic matter and thus low production potential. At altitudes above 2000 metres, there are mountain and meadow-steppe soils, which are used mainly as pasture.

The climate in Armenia is continental, with hot summers and cold winters. The coldest month is January (mean -1.2^0 C) and the hottest months are July and August (mean 25.8^0 C). Annual precipitation varies between 250 mm in southern part of country to 450 mm in the north. About 35,000 ha are out of use because of primary and secondary (mainly) salinisation and 15,000 ha because of waterlogging (underground water at 1-2 m depth). In total about 200,000 ha of agricultural land across the country is out of use for a variety of reasons.

1. 2 Science and Education

Armenia has developed a good infrastructure of high-schools, scientific/research, technical and technological institutions and corresponding science and technical capacity. The experienced scientific schools and subdivisions performing fundamental and applied research in various fields were founded within these institutions. Owing to the activities of these institutions, the intellectual potential of many thousand scientific and technical skilled personnel has been developed across several decades.

Most Armenian scientific institutions specialized in fundamental research are included in the Armenian National Academy of Sciences (ANAS). Under the supervision of the Presidium of ANAS (1943-present), about 40 research institutes and centres conduct fundamental and applied research in humanitarian, natural, and physico-mathematical and technical sciences. Among them are as the oldest research institutes, founded in 1935-1947 (Byurakan Astrophysical Observatory, Institute of Botany, Institute of Geological Science, Institute of History, Institute of Hydroecology and Ichthyology, Institute of Hydroponics Problems, Institute of Organic Chemistry, Institute of Zoology, L.A. Orbeli Institute of Physiology, The Hrachja Atcharian Institute of Language), as well as newly organized research centres, founded in 1990-1999 (Center of Ecological Noosphere Studies, Centre of Medical Genetics, Engineering Center, Institute-Museum of Genocide, State Microbial Depository Research Centre). The International Scientific and Educational Centre of ANAS provides a wide range of programmes for training specialists in different science disciplines.

Among non-academic scientific organizations (totally more than 50) the most well-known are Scientific Research Institute of Biotechnology, Yerevan Physics Institute, Center for the Advancement of Natural Discoveries using Light Emission (CANDLE), National Institute of Health, Research Institute of Economics, Research Institute of Oncology, and Research Institute of Hematology.

There are more than 40 governmental and private higher educational institutions in Armenia. Armenian State Agrarian University, State Engineering University of Armenia, Yerevan State Academy of Fine Arts, Yerevan State Institute of National Economy, Yerevan State Linguistics University, Yerevan State Medical University, Yerevan State University, and Yerevan State

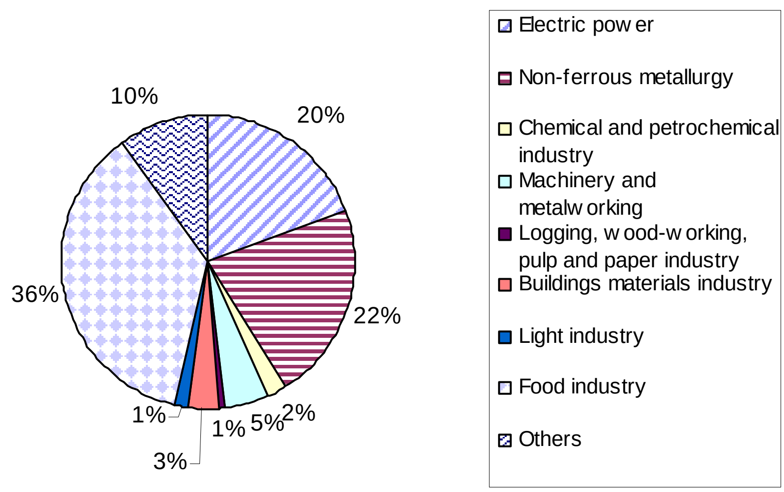
University of Architecture & Construction are the most prestigious Armenian `temples' of education. Among them the oldest one is Yerevan State University, established in 1919.

1.3 Industry

Only 20 years ago Armenia was a highly developed industrial country where chemistry (from large production to fine organic drug production), mechanical engineering (mostly engines), extractive industry and ore processing represented key activities. The two powerful problems that undermined the industrial sector were criminal privatization and destruction of the Soviet general market.

This market was organized in an unusual way – separate parts of the end-product were produced in different republics of the former USSR, and then transferred to one place where a complete product was developed. Notably, mining industry (the extraction and concentration of non-ferrous metals, including copper, molybdenum and gold) is still surviving. Among other branches that have survived are power and food industry. The market structure of currently available industrial products is shown in Figure 1.

Figure 1. Structure of Industrial Production (2003) (% contribution)



1. 4 Agriculture

Armenia became an independent country in May 1991 following the disintegration of the former Soviet Union. The former 869 large collective and state farms on some 147,000 separate parcels were privatized during the 1992 privatization to produce 338,000 farms with small pieces of land. However, the rapidity and disorganization of land reallocation led to disputes and dissatisfaction among the peasants, with conflicts particularly arising over allocation of water rights and distribution of basic materials and equipment.

The average farm size is now 1.37 ha, with a range from 0.61 ha in the Ararat valley to 3.0 ha in pre-mountain and mountain areas. These have on average three parcels of land, one of which is irrigated and two non-irrigated. Some 88% of the farms are smaller than 2 ha and they comprise 77% of the total land area, 12% of the farms are larger than 2ha, using 23% of land. About 15% of farmers also cultivate leased land with average holding size of 3.2 ha and about a third of farmers do not cultivate all their land, mainly due to the poor quality of land, lack of water or distance from the farm.

Agricultural reforms are continuing, with a number of problems yet to be solved. The majority of farms are now just about self-sufficient, though unable to produce the volume required for commercial enterprise. Small farmers both produce food for their family and sell small surpluses on the market. The improvement of farm production systems requires a well-operating processing industry, marketing and technical assistance, a loan system, and an effective extension service. The extension service has been operating for ten years, but has not yet become self-sustainable and survives only with support from international organizations. Nevertheless, some progress has occurred (see Table 1).

Table 1. Gross agricultural output by types of farms (at current prices, billion drams)

	1999	2000	2001	2002	2003
Agriculture	311.7	281.2	351.0	377.6	410.1
Crop cultivation	180.0	136.2	208.0	226.6	228.7
Animal husbandry	131.7	145.0	143.0	151.0	181.4

Since 1992, there has been an increase in food and agriculture's contribution to the country's GDP, and is now calculated to be 30-40%. Crop yields, though, are still generally low, and with the country's current agro-ecological conditions, these yields could rise further. As a result of differing climatic conditions at different altitudes, there are a wide range of fruits and berries available both for fresh use and processing. Armenia is especially rich in apricot, grape, peaches, apples, plums, pears, pomegranates, quinces, figs, walnuts and other fruits.

Agroecological conditions also permit the cultivation of many varieties of vegetables, including tomato, pepper, eggplant, cabbage, potato, cucumber, carrot, pumpkin, bean, garden radish, parsley, basil, coriander, mint, fennel, estragon, cress, cauliflower, lettuce, water melon, melon and peas. Winter wheat and spring barley are the dominant cereals. Maize is mainly grown for feed, in mountainous area cultivation of rye and oats is limited. Alfalfa, sainfoin, clover, amaranth, feed beet and vetch are grown as feed crops, and of industrial crops, only a small amount of tobacco is cultivated. The main crop production data are shown in Table 2.

Cattle, pig, poultry and sheep breeding are the most developed branches of animal breeding in Armenia. The gross output of livestock products is approximately half of the overall agricultural production. A summary of livestock number and productivity are shown in Table 3. Table 4 summarises the per capita production of the main agricultural products.

Table 2. Production of main types of agricultural output(1000 tonnes)

	1999	2000	2001	2002	2003
Grain	301	225	367	415	310
of which wheat	214	178	241	284	217
Tobacco	1.9	4.6	2.5	2.7	1.2
Potatoes	414	290	364	374	507
Vegetables	449	376	456	466	569
Melons and water melons	89	53	55	90	115
Fruit and berries	88	129	102	83	103
Grape	115	116	117	104	82
Meat (slaughter weight)	49	49	48	50	53
Milk	456	452	465	489	513
Eggs (million)	326	385	448	477	502
Wool	1.3	1.3	1.1	1.1	1.1

Table 3. Number (000 head) and productivity (kg) of livestock and poultry

	1999	2000	2001	2002	2003
Cattle	479	497	514	536	566
Sheep and goats	549	540	592	602	628
Pigs	71	69	98	111	85
Horses	12	11	12	12	13
Poultry	4255	3975	3120	3604	3830
Milk per cow (kg)	1708	1668	1685	1708	1728
Wool per sheep (kg)	2.4	2.4	2.2	2.2	2.2
Eggs per layer hen	85	108	160	163	165

Table 4. Production of main agricultural goods (kg per capita)

	1999	2000	2001	2002	2003
Meat (slaughter weight)	13	13	13	16	16
Milk	120	119	122	152	160
Eggs (number)	86	101	118	149	156
Grain (after processing)	79	59	97	130	97
Vegetables	118	98.7	120	145	177
Melons and water melons	23	14	14	28	36
Potatoes	109	76	96	117	158
Fruit and berries	23	34	27	26	32
Grape	30	31	31	32	25

The Armenian food processing industry has in the past focused on the production of sweet jams, juices, tomato paste, and vegetable marinades for both the domestic and foreign markets. Armenian apricot and peach jams and juices have a unique taste and flavor. However, a decrease in the production capacities of the processing factories has occurred during the past 15 years, occurring because of weaknesses in the overall economy. By the year 1997, most processing enterprises were operating at only 5-10% of their former capacity. Recent years have seen some revitalization due to the gradual establishment of localised food production and marketing infrastructure. The canned food processing industry now has 14 plants with a total capacity of more than 300,000 tonnes, among them are several large canneries. As a result, the volume of export of Armenian agro-products is growing, and during 2003 it grew 30-40 times compared with 2002.

There are also favorable natural conditions in Armenia for the production of European cheese types, which remain in great demand. In the past, Armenia was a well-known cheese producing country, supplying 34,000 tonnes of cheese locally and for export, including 1,200 tonnes of Swiss and Swiss type cheeses and 800 tonnes of Roquefort cheese per year. At present a range of cheese factories, all privatized, are actively involved in production of European and traditional Armenian cheeses. Dairies are also producing ice cream, yogurt, sour cream and other products. The wine and brandy industry remains one of the most important branches of the Armenian economy, with 35 wineries, three brandy distilleries and one sparkling wine plant.

Armenian agricultural products could enter international markets if they were to be equipped with modern processing and packaging technologies. However, most local food processing enterprises own outdated equipment and are looking for foreign partners to upgrade existing facilities.

1.5 Biodiversity Conservation Programmes in Armenia

Most biodiversity conservation activities in Armenia are managed by the government. In-situ conservation of biodiversity occurs both in protected areas and in the wider landscape, mainly on lands under State ownership. The Law on Privatisation makes biodiversity conservation on private lands the responsibility of the owner. However economic factors and lack of information mean that the level of protection for biodiversity on private land is poor.

The existing system for protected areas in Armenia was established in 1958, and the network currently covers around 311,000 ha, or 10% of the total area of the country. At least 60% of the species of fauna and flora found in Armenia are represented within the protected area system. Four types of protected areas are recognised under existing laws: state reserves, state conservation areas, national parks and natural monuments.

i. State Reserves have a protection status equivalent to IUCN category 1a Protected Areas (i.e. strict nature reserves, with activities limited to conservation and scientific research). Five State Reserves have been established in Armenia, covering a total of 68,000 ha.
ii. State Conservation Areas were established in Armenia between 1950 and 1970. Of 22 State Conservation Areas, 15 are managed by the Ministry for Nature Protection, six are controlled by the Ministry of Agriculture, and one by the Institute of Physics.
iii. A National Park was established in 1978 at Lake Sevan, and this covers 150,000 ha, including the lake surface (125,200 ha) and 24,800 ha of surrounding land. The national park is managed by the Ministry for Nature Protection.
iv. Natural Monuments are selected according to international criteria, and include both living and geological sites of academic, historic or cultural importance. However, the natural monuments of Armenia have not been officially surveyed and registered, so their precise number is unknown.

Prior to the collapse of the former Soviet Union, a number of laws regulated biodiversity conservation outside protected areas, including human activities around rivers, water catchments and resorts, use of pastures, and collection of species. However, many of these regulations are now outdated, and do not take account of the new economic situation. Three regulations are implemented by the Ministry of Nature Protection: (1) licensing of hunting and fisheries; (2) licensing for the collection and storage of wild medicinal plants; and (3) ecological assessment of any new business activity.

However, public awareness of biodiversity remains relatively low in Armenia. Little information on this issue is broadcast on State radio or television, although articles about the environment appear regularly in the press. The only television programme about nature is broadcast twice a month, but generally presents foreign documentary films, rather than describing the problems facing biodiversity and its protection in Armenia. The popular science magazine (Armenian Nature), which discussed many issues relating to biodiversity conservation, was produced until 1995 but then folded due to financial difficulties. The Ministry of Nature Protection has published a newsletter (Nature) since 1998, which includes many articles on environmental protection. However the print run and distribution of this publication is very limited.

International recognition of the importance of public awareness has resulted in the development of the UN Convention on Access to Information, Public Participation Decision-Making, and Access to Justice in Environmental Matters. Armenia signed on to this convention at Aarhus in 1998, and once the government ratifies the document the dissemination of environmental information and mechanisms for public participation will be clarified.

Various projects, funded through international sources, have been undertaken in Armenia, and underline the global significance of biodiversity conservation. These projects include:

- A review of Forest Sector Development, financed by FAO (1993-1995);
- The Country Study on Climate Change, financed by GEF (1997-1999);
- A Forest Resources Assessment, funded by the Swedish International Development Agency (1998);
- The Lake Sevan Action Plan, funded by the World Bank;
- The National Environmental Action Plan includes a review of issues relating to biodiversity conservation and sustainable use of biodiversity, and a number of priority areas for action were identified. The data and priorities identified by the NEAP have been incorporated wherever possible into the BSAP to ensure the plans are compatible and mutually reinforcing

1.6 Water Resources

Armenia’s water resources constitute 9 billion cubic metres annually, of which only 2 billion is being used. During the soviet period, due to the extremely cheap cost of electricity, instead of construction of Alpine water reservoirs enabling a rational use of water, economically unprofitable water-pumping systems (from down to up) were widely constructed.

However, in recent times, there have been some changes. During the last five years, more than $100 million has been spent to increase capacity and strengthen Alpine water reservoirs. Nonetheless, Armenia’s irrigation system still needs huge investments, as the current irrigation system transfers water with 50% losses (the best parts of the irrigation system are Shamiram and Argishti channels that are 2000-3000 years old). Furthermore, during the watering itself, half of the water is also being lost because of old technologies and imperfect management system.

Accounting for extremely unfavorable situation with water in Middle East countries together with problems with drinking water supply that have experienced for about 20% of world population, it is clear that revision of water management system in Armenia and development of sustainable strategy for efficient use of water would bring sufficient dividends to the country.

1.7 Soil salinity

Proper water management policy can not only promote salt evasion but also a partial use of salty water for irrigation purposes, as it is in Israel, for example. The Ararat valley, which represents only 13% of Armenia's arable lands, provides almost the half of total agricultural production. It is possible due to long vegetation period and also because there are several harvests per year. The next important factor is the presence of water. The main water sources and the surface artesian waters are more or less developed water systems. Notably, in some places water is so close to the ground that it impedes the cultivation of orchards; often these areas have become wetlands, which may cover 5-10,000 ha in some years. Another 5000 ha of is primarily saline, unusable soil originated from anomalous processes of soil genesis. Their recovery is very expensive and difficult.

Presently about 65,000 ha of land in Ararat valley is being cultivated from which one third is gardens and two-thirds is arable land. In comparison, areas of secondary saline soil, which constitute about 30,000 ha, represent a considerable area of land. Secondary saline land arises as a result of both application of inappropriate agricultural techniques and irrational water use. Because of powerful insolation processes and localisation of underground water close to the surface, there is increased water evaporation and plant transpiration. As a result, when water containing just 1 gram salt is not used rationally, it can lead to the appearance of 10 tonnes of salt in one hectare annually. Soils that contain more than 0.1% of salt are considered saline soils. Soil containing 0.5% of salt causes many problems and rapidly becomes desertified.

In order to change the situation and to increase the cultivated areas by half, it will be necessary to strengthen drainage systems, which currently is being done, and move to a more rational use of water, which is not being done.

1.8 Key Problems and Trends

The problems that have arisen in the agricultural sector reflect the peculiarities of the transition period, and the difficulties of entering a market economy. These problems include the collapse of the former systems of financing and material-technical supply; land arrangement inefficiencies; the maintenance of soil quality and other agro-technical measures; and the failure of overly-centralized production, processing and marketing of agricultural products.

There are also serious obstacles to entry into a free market system, including the defects of the current legislative basis; the lack of sufficient financial-credit mechanisms; limited accessibility to foreign markets (due in part to an inability to certify acceptable levels of food quality); low competitive potential of many products; and the near insolvency of many farmers. In addition, the country is in a high-risk zone for agricultural activities, and the primary productive quality of land has deteriorated in many places, as a result of both human activities and natural processes.

To overcome the factors hindering development of the agricultural sector, the following policies reforms will have to be pursued:

i. Creating the conditions for the formation and expansion of the agricultural land market, land consolidation;
ii. Increasing soil fertility and effectiveness of land use through adoption of soil-recovery technologies and practices;
iii. Supporting the development and renovation of physical infrastructure which contributes to development of agriculture (e.g., improved roads in farm areas, irrigation systems, drainage systems);
iv. Implementing financial and organizational reforms of the irrigation system so as to increase the efficiency of irrigation;
v. Introducing a market system of insurance in agriculture.

Other areas where reforms and/or improvements can promote formation of a sustainable system of agriculture in Armenia include further improvement of the legal framework; expansion of financial credit mechanisms; attraction of new investments to all phases of agricultural production (farming, processing, transport, marketing, etc.); development of cooperatives for production and marketing; refinement of agro-technical and production-technical support; and introduction of better farming methods, and related training programs for farmers.

2. Principles for Agricultural Sustainability

2.1 The Wider Challenge

Much of the current interest in the sustainability of agricultural and food systems can be traced to environmental concerns that began to appear in the 1950s and 1960s. However, ideas about sustainability date back at least to the oldest surviving writings from China, Greece and Rome. Today, concerns about sustainability centre on two key issues:

1. Agricultural technologies and practices that do not have adverse effects on the environment (partly because the environment is an important asset for farming).

2. Agricultural technologies and practices that are accessible to poor farmers and their families, and lead to improvements in productivity and reductions in poverty.

Sustainability in agricultural systems is about both resilience (the capacity of systems to buffer shocks and stresses) and persistence (the capacity of systems to carry on), and addresses economic, social and environmental outcomes.

Why is there a concern about sustainability? Agriculture has performed remarkably well in recent decades. There have been startling increases in food production across the world since the beginning of the 1960s, since when world population has grown from three to six billion, and per capita agricultural production has increased by 25%. In Asia and Latin America, per capita food production increased by 76% and 28% respectively. Africa, though, has fared badly, with food production per person 10% less today than in 1960.

However, these advances in aggregate productivity have not brought reductions in incidence of hunger for all. In the early 21st century, there are more than 800 million people hungry and lacking adequate access to food. In addition, the success of modern agriculture has been accompanied by four critical environmental challenges:

1. *Land degradation* – worldwide, some 2 billion hectares of land are degraded by water and wind erosion, by contamination from industry and agriculture (including pesticides and fertilizers), and by overuse of irrigation water causing salinisation.

2. *Water use and availability* – one fifth of the world's cropland is irrigated, and this produces 40% of the world's food. There are few remaining opportunities to expand irrigation cheaply. Most farmers are entirely dependent on rainfall, which is becoming increasingly uncertain in the face of climate change.

3. *Losses of biodiversity* – diverse agricultural systems and landscapes are resilient to shocks and stresses, making use of helpful plants, insects and animals to control pests and keep soils fertile. Many of the world's modern agricultural systems have now become highly-simplified, no longer making the best use of useful biodiversity.

4. *Declining genetic diversity in agriculture itself* – only 150 plant species are cultivated for food worldwide, and only 3 (rice, wheat and maize) supply 60% of the world's calories. Genetic diversity in crops has been spiraling downwards – some 30,000 varieties of rice were grown in India fifty years ago; now 10 varieties cover 75% of the all the rice area.

The costs of these problems are often called externalities, and so they do not appear on any balance sheet. Yet many agricultural systems themselves suffer by undermining key natural assets that they require to be successful. The current challenge is enormous. Growth in food production, combined with economic growth in rural areas, is an essential priority for many developing countries. Yet this must be targeted towards poverty alleviation combined with maintenance of, and even improvements to, the natural resource base.

2.2 The Development of Ideas about Sustainability

Although farmers throughout history have used a wide range of technologies and practices we would today call sustainable, it is only in recent decades that the concepts associated with sustainability have come into more common use.

Concerns began to develop in the 1960s, and were particularly driven by Rachel Carson's book *Silent Spring* (Carson, 1963). Like other popular and scientific studies at the time, it focused on the environmental harm caused by agriculture. In the 1970s, the Club of Rome identified the economic problems that societies would face when environmental resources were overused, depleted or harmed, and pointed towards the need for different types of policies to generate economic growth.

In the 1980s, the World Commission on Environment and Development, chaired by Gro Harlem Brundtland, published *Our Common Future,* the first serious attempt to link poverty alleviation to natural resource management and the state of the environment. Sustainable development was defined as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"*. The concept implied both limits to growth and the idea of different patterns of growth (WCED, 1987).

In 1992, the UN Conference on Environment and Development was held in Rio de Janeiro. The main agreement was Agenda 21, a 41 chapter document setting out priorities and practices in all economic and social sectors, and how these should relate to the environment. Chapter 14 addressed Sustainable Agriculture and Rural Development (SARD). The principles of sustainable forms of agriculture that encouraged minimizing harm to the environment and human health were agreed. However, progress has not been good, as Agenda 21 was not a binding treaty on national governments, and all are free to choose whether they adopt or ignore such principles (Pretty and Koohafkan, 2002).

The "Rio Summit" was followed by several important actions that came to affect agriculture:

1. The signing of the Convention on Biodiversity in 1995.
2. The establishment of the UN Global IPM Facility in 1995, which provides international guidance and technical assistance for integrated pest management.
3. The signing of the Stockholm Convention on Persistent Organic Pollutants in 2001, so addressing some problematic pesticides.
4. The ten years after Rio World Summit on Sustainable Development held in Johannesburg.

The concept of agricultural sustainability has grown from an initial focus on environmental aspects to include first economic and then broader social and political dimensions (Cernea, 1991; DFID, 2002).

- *Ecological* – the core concerns are to reduce negative environmental and health externalities, to enhance and use local ecosystem resources, and preserve biodiversity. More recent concerns include broader recognition for positive environmental externalities from agriculture (including carbon capture in soils and flood protection).

- *Economic* – economic perspectives seek to assign value to ecological assets, and also to include a longer time frame in economic analysis. They also highlight subsidies that promote the depletion of resources or unfair competition with other production systems.

- *Social and political* – there are many concerns about the equity of technological change. At the local level, agricultural sustainability is associated with farmer participation, group action and promotion of local institutions, culture and farming communities. At the higher level, the concern is for enabling policies that target poverty reduction.

2.3 Agricultural Sustainability

All commentators agree that food production will have to increase substantially in the coming years. But there are very different views about how best this should be achieved (Conway, 1997; NRC, 2000; Smil, 2000; Trewevas, 2002; Pretty, 2002; Tilman *et al.*, 2002, McNeely and Scherr, 2003; Nuffield Council on Bioethics, 2004; Pretty *et al*., 2006):

- Some say agriculture will have to expand into new lands – but this will mean further losses of biodiversity.
- Others say food production growth must come through redoubled efforts to repeat the approaches of the Green Revolution.
- Others still say that agricultural sustainability offers options for farmers to intensify their land use and increase food production.

But solving the persistent hunger problem is not simply a matter of developing new agricultural technologies and practices. Most poor producers cannot afford expensive technologies. They will have to find new types of solutions based on locally-available and/or cheap technologies combined with making the best of natural, social and human resources.

What do we understand by agricultural sustainability? Many different terms have come to be used to imply greater sustainability in agricultural systems over prevailing systems (both pre-industrial and industrialised). These include sustainable, ecoagriculture, permaculture, organic, ecological, clos-to-nature, low-input, biodynamic, environmentally-sensitive, community-based, wise-use, farm-fresh and extensive. There is intense debate about whether agricultural systems using some of these terms qualify for the term sustainable (Altieri, 1995; Pretty, 1995).

A common, though erroneous, assumption has been that agricultural sustainability approaches imply a net reduction in input use, and so are essentially extensive (they require more land to produce the same amount of food). All recent empirical evidence shows that successful agricultural sustainability initiatives and projects arise from changes in the factors of agricultural production (e.g. from use of fertilizers to nitrogen-fixing legumes; from pesticides to emphasis on natural enemies). However, these have also required reconfigurations on human capital (knowledge, management skills, labour) and social capital (capacity to work together) (Li Wenhua, 2001; Pretty and Ward, 2001; Uphoff, 2002).

A better concept than extensive, therefore, is to suggest that sustainability implies intensification of resources – making better use of existing resources (e.g. land, water, biodiversity) and technologies. For many, the term intensification has come to imply something bad – leading, for example, in industrialised countries to agricultural systems that impose significant environmental costs. The critical question centres on the `type of intensification'.

Intensification using natural, social and human capital assets, combined with the use of best available technologies and inputs (best genotypes and best ecological management) that minimise or eliminate harm to the environment, can be termed `sustainable intensification'(Pretty *et al*., 2003, 2006).

Agricultural systems at all levels rely for their success on the value of services flowing from the total stock of assets that they control, and five types of asset, natural, social, human, physical and financial capital, are now recognised as being important (Costanza *et al*., 1997; Pretty and Ward, 2001; Pretty, 2002; Uphoff, 2002; Pretty, 2003, 2004).

Natural capital produces nature's goods and services, and comprises food, both farmed and harvested or caught from the wild, wood and fibre; water supply and regulation; treatment, assimilation and decomposition of wastes; nutrient cycling and fixation; soil formation; biological control of pests; climate regulation; wildlife habitats; storm protection and flood control; carbon sequestration; pollination; and recreation and leisure.

Social capital yields a flow of mutually beneficial collective action, contributing to the cohesiveness of people in their societies. The social assets comprising social capital include norms, values and attitudes that predispose people to cooperate; relations of trust, reciprocity and obligations; and common rules and sanctions mutually-agreed or handed-down. These are connected and structured in networks and groups.

Human capital is the total capability residing in individuals, based on their stock of knowledge skills, health and nutrition. It is enhanced by access to services that provide these, such as schools, medical services, and adult training. People's productivity is increased by their capacity to interact with productive technologies and with other people. Leadership and organisational skills are particularly important in making other resources more valuable.

Physical capital is the store of human-made material resources, and comprises buildings, such as housing and factories, market infrastructure, irrigation works, roads and bridges, tools and tractors, communications, and energy and transportation systems, that make labour more productive.

Financial capital is more of an accounting concept, as it serves as a facilitating role rather than as a source of productivity in and of itself. It represents accumulated claims on goods and services, built up through financial systems that gather savings and issue credit, such as pensions, remittances, welfare payments, grants and subsidies.

As agricultural systems shape the very assets on which they rely for inputs, a vital feedback loop occurs from outcomes to inputs. Thus sustainable agricultural systems tend to have a positive effect on natural, social and human capital, whilst unsustainable ones feed back to deplete these assets, leaving less for future generations. For example, an agricultural system that erodes soil whilst producing food externalises costs that others must bear. But one that sequesters carbon in soils through organic matter accumulation helps to mediate climate change. Similarly, a diverse agricultural system that enhances on-farm wildlife for pest control contributes to wider stocks of biodiversity, whilst simplified modernised systems that eliminate wildlife do not. Agricultural systems that offer labour-absorption opportunities, through resource improvements or value-added activities, can boost economies and help to reverse rural-to-urban migration patterns.

Agriculture is, therefore, fundamentally multifunctional. It jointly produces many unique non-food functions that cannot be produced by other economic sectors so efficiently. Clearly, a key policy challenge, for both industrialised and developing countries, is to find ways to maintain and enhance food production. But the key question is: can this be done whilst seeking both to improve the positive side-effects and to eliminate the negative ones? It will not be easy, as past agricultural development has tended to ignore both the multifunctionality of agriculture and the pervasive external costs (Pretty, 2002; Pretty *et al*., 2003; Dobbs and Pretty, 2004).

This leads us to a simple and clear definition for sustainable agriculture. It is farming that makes the best use of nature's goods and services whilst not damaging the environment. It does this by integrating natural processes such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests into food production processes. It also minimises the use of non-renewable inputs that damage the environment or harm the health of farmers and consumers. It makes better use of the knowledge and skills of farmers, so improving their self-reliance, and it makes productive use of people's capacities to work together to solve common management problems. Through this, sustainable agriculture also contributes to a range of public goods, such as clean water, wildlife, carbon sequestration in soils, flood protection and landscape quality.

A more sustainable farming seeks to make the best use of nature's goods and services whilst not damaging the environment. It does this by integrating natural processes such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests into food production processes. It also minimizes the use of non-renewable inputs that damage the environment or harm the health of farmers and consumers. It makes use of the knowledge and skills of farmers, so improving their self-reliance, and it seeks to make productive use of people's collective capacities to work together to solve common management problems, such as pest, watershed, irrigation, forest and credit management.

Sustainable agriculture is also multi-functional within landscapes and economies – it jointly produces food and other goods for farm families and markets, but it also contributes to a range of public goods, such as clean water, biodiversity, carbon sequestration in soils, groundwater recharge and flood protection. As sustainable agriculture also seeks to make the best use of nature, so technologies and practices must be locally-adapted. They are most likely to emerge from new configurations of social relations, comprising relations of trust embodied in new social organizations, and new horizontal and vertical partnerships between institutions, and human capacity, comprising leadership, ingenuity, management skills and capacity to innovate. Thus agricultural systems with high levels of social and human capital are more able to innovate in the face of uncertainty.

2.4 Technologies for Sustainability

The idea of agricultural sustainability centers on food production that makes the best use of nature's goods and services whilst not damaging these assets. Agricultural sustainability in all cases emphasises the potential benefits that arise from making the best use of both genotypes of crops and animals and their ecological management. Agricultural sustainability does not, therefore, mean ruling out any technologies or practices on ideological grounds – provided they improve productivity for farmers, and do not harm the environment.

Improvement in total household food production can occur through one or more of four different mechanisms in agricultural systems:

i. the intensification of a single component of a farm system, with little change to the rest of the farm, such as home garden intensification with vegetables or tree crops, vegetables on rice bunds, and introduction of fish ponds or a dairy cow;

ii. the addition of a new productive element to a farm system, such as fish or shrimps in paddy rice fields, or trees, which provide a boost to total farm food production and/or income, but which do not necessarily affect cereal productivity;

iii. the better use of natural resources to increase total farm production, especially water (by water harvesting and irrigation scheduling), and land (by reclamation of degraded land), so leading to additional new dryland crops and/or increased supply of additional water for irrigated crops (both increasing cropping intensity);

iv. improvements in per hectare yields of staple cereals through introduction of new regenerative elements into farm systems, such as legumes and integrated pest management, and new and locally-appropriate crop varieties and animal breeds.

The technologies themselves are often incorporated into packages. These include:

1. *Integrated pest management*, which uses ecosystem resilience and diversity for pest, disease and weed control, and seeks only to use pesticides when no other options are available.

2. *Integrated nutrient management*, which seeks both to balance the need to fix nitrogen within farm systems with the need to import inorganic and organic sources of nutrients, and to reduce nutrient losses through erosion control.

3. *Conservation tillage*, which reduces the amount of tillage, sometime to zero, so that soil can be conserved and available moisture used more efficiently.

4. *Agro forestry,* which incorporates multifunctional trees into agricultural systems, and collective management of nearby forest resources (*joint forest management*).

5. *Aquaculture*, which incorporates fish, shrimps and other aquatic resources into farm systems, such as into irrigated rice fields and fish ponds, and so leads to increases in protein production. Such type of incorporation should not be just mechanical, but has to keep minimization principle of energy consume and of use of products with side effect; in “Mera” the system of zeolite filters is being developed which are able to clean water from nitrogen compounds and enriched with oxygen while moving from one pond to another and after which these filters can be used as soil conditioners enriched with nitrogen (see Annex A).

6. *Water harvesting* in dryland areas, which can mean formerly abandoned and degraded lands can be cultivated and additional crops grown on small patches of irrigated land owing to better rain water retention.

7. *Livestock integration* into farming systems, such as dairy cattle and poultry, including using zero-grazing. Using manure in any stages of its treatment (compost, biohumus, buy product of biogas production).

2.5 Some Opportunities for Agricultural Improvement

Despite the fact that the Soviet administration has been destroyed, Armenian society lacks healthy (non-hierarchical) horizontal relations. Command style authorities appear to be stuck in corruption, and non-governmental organizations are generally weak and do not participate in social life. The institute of independent experts does not work (Hykazyan, 2004). And instead of elaborating and implementing a strategy of a certain economic sector, the ministries are busy with their administration. The situation could be partly improved by the sequential development of participatory principles.

The next important step towards success is the consolidation and cooperation of small farms which will allow the more effective treatment of the land, management of farm activities, and linkages to processing and sales of agricultural produce. The closing down of the chemical industry has created opportunities to encourage more ecological approaches in agriculture. Factories do not produce chemical fertilizers and their import requires huge transport costs. In such conditions, the switch to organic farming appears more beneficial, especially when the quantity of agricultural animals allows not only to treat land with organic fertilizers but also to export concentrated bioorganic fertilizers.

The existence of large amounts of mountain pasture (half of the total area used for farming purposes) is an opportunity to have ecologically pure products not only from crops but also from animal husbandry. As elsewhere in the whole world, soil degradation remains a significant problem, often severe enough to prevent good crop yields.

The increase in a total number of hungry people during the next decade means that there should be a serious reconsideration of the available approaches to increase crop productivity. Those chosen or newly developed should be ecologically reliable. Such new approaches should be based upon two main principles: i) methods should work at high level of organization (from molecular biology and biotechnology to net-productivity of crops); ii) there should be maximum usage of natural resources (resource of plant plus resource of its environment – light, nutrition elements, water, and carbon dioxide) (Haykazyan, 2005a). An example of a sustainable farm, Mera 99, is described in Annex A. Presently the national interest in natural resources, organic agriculture and biointensive methods is low, but beginning to increase.

Much attention needs to be paid to saline soils, and the selection of appropriate crop types, eg those which give small decreases in productivity under conditions when nothing is spent for washing soil or other ameliorative works (Haykazyan, 2005b). Soil improvement is a major challenge. Instead of the earlier used mechanical and mechano-chemical soil-improvers, currently multifunctional soil-improvers with high holding and exchange capacity (zeolite represents the most widely used multifunctional soil-improver) are being more widely used. Furthermore, microbial and bioorganic soil-improvers, having humus-formation abilities, have been also tested.

Together with these agricultural approaches, attention is also concentrated upon technologies where micro-quantities of active substances are used. Those include promoters of photosynthesis, which mostly increase duration of the leaf cover. They probably simultaneously are acting as selective small-scale agents, capable of removing the limits of photosynthesis and provide intensive gas-exchange without sufficient loss of water for transpiration (Mirzakhanyan *et al*., 2005).

Among nano-technological approaches, extra-root trace element nutrition of agricultural crops is also promising. Combining transport of water and nutritional elements (by electrochemical potential gradient) with selective transport (against gradient) a plant expends huge amounts of energy, particularly in the conditions of salinization, when additional charge take place as a result of difficult regulation of transpiration and salt compartmentalization. Extra-root microelement nutrition removes the necessity of such energy expenditure and results in increases in productivity (Yeritsyan *et al*., 2005).

3. Policy Recommendations

3.1 Recent Policy Progress Across the World

Three things are now clear from evidence on the recent spread of agricultural sustainability:

i. Some technologies and social processes for local scale adoption of more sustainable agricultural practices are increasingly well-tested and established;
ii. The social and institutional conditions for spread are less well-understood, but have been established in several contexts, leading to more rapid spread in the 1990s and early 2000s;
iii. The political conditions for the emergence of supportive policies are least well established, with only a very few examples of real progress.

Most agricultural sustainability improvements seen in the 1990s and early 2000s have arisen despite existing national and institutional policies, rather than because of them. Although almost every country would now say it supports the idea of agricultural sustainability, the evidence points towards only patchy reforms. Only three countries have given explicit national support for sustainable agriculture – putting it at the centre of agricultural development policy and integrating policies accordingly:

- Cuba has a national policy for alternative agriculture;
- Switzerland has three tiers of support to encourage environmental services from agriculture and rural development;
- Bhutan has a national environmental policy coordinated across all sectors.

Several countries have given significant sub-regional support to agricultural sustainability (Pretty, 2002), including:

- the states of Santa Caterina, Paraná and Rio Grande do Sul in southern Brazil supporting zero-tillage, catchment management and rural agribusiness development
- some states in India supporting participatory watershed and irrigation management
- China's support for integrated ecological demonstration villages,
- Kenya's catchment approach to soil conservation,
- Indonesia's ban on pesticides and programme for farmer field schools,
- Bolivia's regional integration of agricultural and rural policies,
- Burkina Faso's land policy,
- Sri Lanka and the Philippines' stipulation that water users' groups be formed to manage irrigation systems.

A good example of a carefully designed and integrated programme comes from China. In March 1994, the government published a White Paper to set out its plan for implementation of Agenda 21, and put forward ecological farming, known as *Shengtai Nongye* or agro-ecological engineering, as the approach to achieve sustainability in agriculture. Pilot projects have been established in 2000 townships and villages spread across 150 counties. Policy for these `eco-counties' is organised through a cross-ministry partnership, which uses a variety of incentives to encourage adoption of diverse production systems to replace monocultures. These include subsidies and loans, technical assistance, tax exemptions and deductions, security of land tenure, marketing services and linkages to research organisations. These eco-counties contain some 12 million hectares of land, about half of which is cropland, and though only covering a relatively small part of China's total agricultural land, do illustrate what is possible when policy is appropriately coordinated (Li Wenhua, 2001).

An even larger number of countries has seen some progress on agricultural sustainability at project and programme level. However, progress on the ground still remains largely despite, rather than because of, explicit policy support. No agriculture minister is likely to say they are against agricultural sustainability, yet good words remain to be translated into comprehensive policy reforms.

3.2 The Need for a Multi-Track Approach

Many countries have national policies that now strongly advocate export-led agricultural development. Access to international markets is clearly important for poorer countries, and successful competition for market share can be a very significant source of foreign exchange.

However, this approach has some drawbacks:

- Poor countries are in competition with each other for market share, and so there is likely to be a downward pressure on prices, which reduces returns over time unless productivity continues to increase;
- Markets for agri-food products are fickle, and can be rapidly undermined by alternative products or threats (e.g. avian bird flu and the collapse of the Thai poultry sector);
- Distant markets are less sensitive to the potential negative externalities of agricultural production and are rarely pro-poor (with the exception of fair-trade products);
- Smallholders have many difficulties in accessing international markets and market information;

There is little clear evidence that export-led poverty alleviation has worked as envisaged. Even Vietnam, which has earned considerable foreign exchange from agricultural development has had to do so at very low prices and little value-added (Lipton, 2004).

More importantly, an export-led approach can seem to ignore the in-country opportunities for agricultural development focused on local and regional markets. Agricultural policies with both sustainability and poverty-reduction aims should adopt a multi-track approach that emphasises five components:

1. Small farmer development linked to local markets;
2. Agri-business development – both small businesses and export-led;
3. Agro-processing and value-added activities – to ensure that returns are maximised in-country;
4. Urban agriculture – as many urban people rely on small-scale urban food production that rarely appears in national statistics;
5. Livestock development – to meet local increases in demand for meat (predicted to increase as economies become richer).

What we do not yet know is how to engage governments in the debate about the various priorities, and then how to implements change in national policies.

3.3 Policy Priorities for Armenia

Some commentators believe that agriculture has become marginalised in most industrialised countries, with other social and economic development sectors becoming higher priorities. Recently, however, many development assistance agencies have re-engaged with the agricultural policy debate through a growing recognition that poverty reduction and better livelihoods for poor people cannot be achieved without substantial improvements in agricultural productivity.

What, therefore, should agricultural development do to incorporate emerging ideas about agricultural sustainability into its policies and strategies for wider poverty reduction? The overarching priority is to put the idea of sustainability at the centre of agricultural policies rather than at the edge. Such policies would have implications for all natural resources within Armenia, as well as for all social groups and farm systems.

There are seven more specific priorities:

1. Invest in research and extension for agricultural sustainability – as public-sector research does pay, and public extension systems are essential for adapting and transferring technologies;

2. Invest in both soil management systems to increase organic matter and productivity (spreading simple soil-improving technologies);

3. Engage in debate over appropriate land reform, as poor people cannot be expected to invest in asset building (especially of natural capital) if they have no guarantee over long-term access to their land;

4. Promote support for agricultural development programmes that build rural social capital, particularly for access credit and microfinance;

5. Develop new approaches for supporting small-scale agri-businesses in rural areas (so that food commodities can be value-added before leaving the local economy), such as loan guarantees, underwriting debt, providing equity funds, and providing grants for social infrastructure and community projects;

6. Ensure support for urban agriculture, which is often missed by mainstream agricultural development;

7. Work with farmers’ and rural people’s organisations to develop better methods for accessing market information.

References

Altieri M A. 1995. *Agroecology: The Science of Sustainable Agriculture.* Westview Press, Boulder

Carson R. 1963. *Silent Spring*. Penguin Books, Harmondsworth

Cernea M M. 1991. *Putting People First*. Oxford University Press, Oxford. 2nd Edn

Conway G R. 1997. *The Doubly Green Revolution*. Penguin, London

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neil R V, Paruelo J, Raskin R G, Sutton P and van den Belt M. (1997 and 1999). The value of the world's ecosystem services and natural capital. *Nature* 387, 253-260

DFID. 2002. *Sustainable Agriculture*. Resource Management Keysheet 10. London;

Dobbs T and Pretty J N. 2004. Agri-environmental stewardship schemes and `multifunctionality'. R*eview of Agricultural Economics* 26(2), 220-237

Haykazyan V.2004. *Problems of Armenian Agriculture and Perspectives of Development.* (in Armenian) Hayastan (Analytical Journal), #2, 41-66

Haykazyan V.2005a. *Increase of the AgriculturalCrop Productivity.Possible Changes of Paradigm.(*in Russian, English abstract). XIV International Symposium on Nontraditional Plant Growing. Sympheropol, Ukraine, 105-110

Haykazyan V. 2005b.Saline Soils and Their Usage.(in Armenian), Surb-Ser, Yerevan, 32p.

Lipton M. 2004. Overview for DFID consultation on agricultural sustainability

Li Wenhua. 2001. *Agro-Ecological Farming Systems in China.* Man and the Biosphere Series Volume 26. UNESCO, Paris

McNeely J A and Scherr S J. 2003. *Ecoagriculture.* Island Press, Washington DC

Mirzakhanyan V,, Gyulkhandanyan G., Galstyan M. Haykazyan V.,2005.*The Influence of Zn-modified NaturalPorphyrin Microquantyties for the Recovery and Increase of Winter Wheat Pruductivity* .(in Russian, English abstract). XIV International Symposium on Nontraditional Plant Growing. Sympheropol, Ukraine. p542

NRC. 2000. *Our Common Journey: Transition towards sustainability*. Board on Sustainable development, Policy Division, National Research Council. National Academy Press, Washington DC

Nuffield Council on Bioethics. 2004. *The Use of Genetically Modified Crops in Developing Countries.* London

Pretty J. 1995. Regenerating Agriculture. Earthscan, London

Pretty J N. 2002. *Agri-Culture: Reconnecting People, Land and Nature*. Earthscan, London

Pretty J. 2003. Social capital and the collective management of resources. *Science* 302, 1912-1915

Pretty J. 2004. How nature contributes to mental and physical health. *Spirituality and Health International* 5(2), 68-78

Pretty J N and Koohafkan P. 2002. Land and Agriculture: From UNCED Rio to WSSD Johannesburg. FAO, Rome

Pretty J N and Ward H. 2001. Social capital and the environment. *World Development* 29 (2), 209-227

Pretty J and Smith D J. 2004. Social capital in biodiversity conservation and management. *Conservation Biology* 18(5), 631-638

Pretty J, Morison J I L and Hine R E. 2003. Reducing food poverty by increasing agricultural sustainability in developing countries. *Agric. Ecosys. Environ.* 95(1), 217-234

Pretty J, Noble A D, Bossio D, Dixon J, Hine R E, Penning de Vries F W T and Morison J I L. 2006. Resource-conserving agriculture increases yields in developsing countries. *Environmental Science & Technology* 40 (4), 1114 -1119

Smil V. 2000. *Feeding the World: A Challenge for the 21s Century.* MIT Press, Cambridge MA

Tilman D, Cassman K G, Matson P A, Naylor R and Polasky S. 2002. Agricultural sustainability and intensive production practices. *Nature* 418, 671-677

Trewevas A. 2002. Malthus foiled again and again. *Nature* 418, 668-670

Uphoff N (ed). 2002. *Agroecological Innovations*. Earthscan, London

World Commission on Environment and Development. 1987. *Our Common Future*. Oxford University Press, Oxford

Yeritsyan L., Yeritsyan S., Haykazyan V. 2005. *Complexon CE Influence on theYield of Winter Wheat Cultivated in the Low Salinity Soils of Ararat Valley*.(in Russian,English abstract). XIV International Symposium on Nontraditional Plant Growing. Sympheropol, Ukraine.p557

Annex A: Profile of Mera Eco 99 Farm

The Mera[1] Eco-99 farm is approached from under the gaze of snow-capped Mount Ararat, through the industrial wastelands of deserted fruit-processing factories with shattered windows. The road twists past relics of state-run farms, and over wide irrigation channels flanked with rushes. Two hoopoes flash over the scrubland and settle on the crumbling concrete remains of another building. For much of the 20th century, this agricultural landscape was dominated by large collective farms and agro-industrial complexes. After independence in 1991, agricultural policy switched to small-scale farming, with some 300,000 small plots of land handed back to rural people. About 30,000 hectares of land remain severely salinised, mainly because of past over-irrigation, but also because of the very low levels of organic matter in the light soils. The collective challenge is enormous – how to turn a degraded land with a new farm ownership structure that few people yet understand into a productive landscape?

And this is where the 20 hectare Mera farm could be an exemplar. Set in the middle of a wide valley on salty soils, the land was purchased five years ago by members of Eco-99 NGO, and they have developed here agricultural activities with support from the World Council of Churches' Inter-church Round-Table Foundation of Armenia and UK's Christian Aid and some other donors from Norway. The idea was to turn this wasteland dotted with low scrub into a diverse and productive farm. There were no local models to copy, but the operators had seen and read about farms elsewhere in the world that had intensified their use of locally-available resources to create sustainable and productive farms.

From a distance, it is clear that something unusual is happening at the farm, as its poplars, tamarix and acacia are the only trees apparent in the landscape. Closer up, there is an orchard of apricots, now being rehabilitated. And now it is clear that this farm is doing so much that is different. There are Russian olives, grape vines, and apple, pear, walnut and plum trees. Interspersed are a wide variety of vegetables, including onion, spicy greens, eggplant, cabbage, horseradish, carrot and beets. Patches of herbs – coriander, parsley, basil, sage and dill – indicate their attention to food culture. A couple of smaller fields contain wheat, maize and alfalfa. Cattle are kept for their manures and milk, as sour cream and yoghurt are central to many meals. They key to agricultural success lies in stabilising the soils by adding organic matter, either from animal or green manures. The trees also play a vital role in creating a new microclimate for the farm.

But where the farm also differs is in the two new fishponds that contain some 3000 rainbow trout. These have become a valuable source of income. They are also the location for a touch of animal ingenuity that should make us all think more carefully about our place in the world. People at the farm have noticed more biodiversity since it was established, with more songbirds particularly, and also hedgehogs, frogs, water voles, and herons that come for the fish.

How, then, can this farm be so very different from all those around? The answer lies partly in having access to new or different technologies and practices, and partly in vision and ingenuity. Where do all transformations begin? With an idea, and then hard work, and then demonstration to others that they can do it too. There is no reason why any other farms in the valley should not do the same, but at the moment officials, farmers and consumers do not recognise that anything of value is occurring. But this should change with the plans to develop Mera as an agro-tourism attraction. It is only a short ride from the heavily visited 4th century cathedral at Etchmiadzin, centre of the Armenian church, and people may come to appreciate a farm that is an oasis of good

[1] Mera means mother (in local Armenian dialect)

practice. Here, then, is a small and diverse farm, showing what is possible on formerly salinised soils. As has been seen elsewhere in the world, the deserts and apparent wastelands can become green if people have the ideas, technologies and the strength of purpose.

Another advantage is that the members of Eco-99 NGO, owners of Mera, have permanently disseminated the experience of their success among neighbourhood rural communities, as the main mission of this NGO is agricultural extension.

Annex B: Green Manures and Agroforestry

Legumes and Green Manures

The impact of legumes grown together with or before a cereal crop can reduce, and sometimes eliminate, the need for nitrogen fertilizers. Symbiotic bacteria present in specialised nodules that develop on the roots of legumes can fix nitrogen directly from the atmosphere. The cultivation of cereals and legumes crops together can improve both total yields and stability of production. Bushes and trees with nitrogen-fixing capacity also have beneficial effects on plants growing with or after them.

In the Americas, the interplanting of maize, beans and squash, often the seeds being placed in the same planting hole, is a practice of great antiquity, probably dating to soon after agriculture began in the valleys of Mexico. In such situations, with soils of low inherent fertility, the cultivation of cereals and legumes crops together can improve both total yields and stability of production. In maize and cowpea mixtures, some 30% of the nitrogen taken up by the maize is obtained from the legume. Cowpea and lablab are particularly useful legumes for inter-cropping with cereals, the former because it is adapted to acid, infertile soils, and the latter because it is drought-tolerant, produces good fodder and can regrow well after clipping. Here, legumes contribute not only through nitrogen fixation, but also because the green matter can be used as a mulch or green manure.

Nutrients are also supplied when vegetation is incorporated in the soil as a `green manure'. Green manures increase nutrient levels as well as improve the physical properties of the soil. This has long been practised; the Romans grew lupins and ploughed them in before sowing cereals more than 2000 years ago. Quick-growing legumes are valuable green manures for many low input systems, and have the potential to meet much, if not all, of the nitrogen requirements of succeeding non-legume crops. The equivalent amount of nitrogen fertilizer required to match the green manures can be 80-200 kg/ha. Many green manures can also add large amounts of organic matter, up to 50-100 tonne/ha.

One of the most remarkable is the velvetbean (*Mucuna pruriens*). This has been widely promoted as part of the work of World Neighbors in central America, though its effectiveness is attested by its spontaneous spread from village to village without outside intervention. It grows rapidly, is palatable to animals and humans, fixes large amounts of nitrogen, and can produce as much as 100 t/ha of organic matter. It can grow on most soils, and its spreading habit suppresses weed growth. This compares with an average for the country of just 0.6 t/ha. Incorporating such green manures into cropping systems can substantially increase yields. Honduran and Guatemalan farmers are able to harvest some 2.5-3.2 t/ha of maize when grown after velvetbean.

Sesbania rostrata, though, is probably the fastest nitrogen-fixing plant, accumulating 110 kgN/ha in only 45 days. In Rwanda, the shrub *Tephrosia vogelii* grows to a height of 3 metres in 10 months and produces 14 tonnes/ha of above-ground biomass which, when worked into the soil, can increase cereal yields by as much as four-fold to some 2800 kg/ha, a response equivalent to 120 kg/ha of inorganic fertilizer. In Nepal, some green manures can produce rice yields that outperform those produced by as much as 100:30:30 kg of NPK/ ha. In dryland Northeast Thailand, short duration legumes can be grown following the first rainfall peak, which is insufficient for rice transplanting. Cowpeas, grown for 45-60 days before the rice, have increased rice yields by 5-20% for poor farmers compared with conventional fallowing. The benefits are such that inorganic fertilizers are no longer necessary.

In Bhutan, *Sesbania aculeata* substitutes for external inputs, but the best performance occurs when farmers have access to some inorganic nitrogen. *Sesbania* with no fertilizers produces the same rice yields as 40:40:30 kg NPK/ha; but if fertilizers are added to rice after the *Sesbania* then yields increase to 5.4-5.5 t/ha, levels that can be achieved only if 120 kg N/ha are added. Use of *Sesbania* as a green manure can save the use of between 40-120 kg N/ha. The key lesson would appear to be that green manures increase crop yields significantly by providing nitrogen. But if farmers are able to get hold of small amounts of inorganic nitrogen, then they will benefit still further.

There are 19 million hectares of upland rice worldwide, and average yields are only about 1 tonne/ha. Yet if cowpea or lablab are intercropped with rice, and then allowed to continue growing through the dry season, the biomass can be incorporated as a green manure before the next rice crop (Aggarwal & Garrity, 1987). Rice yields increase to 1.4 - 1.9 t/ha as a result, and there is the added bonus of the legume grain yield of 0.5-1 t/ha.

Recent research in semi-arid India has shown that some legumes, such as chickpea and pigeonpea, have a unique mechanism that allows them to access phosphate in phosphate-poor soils. They release acids from their roots, which react with calcium- and iron-bound phosphate to release phosphate for plant uptake. As their deep rooting also helps water infiltration, they have a positive residual affect on subsequent crops, as both phosphate and water availability are increased.

Table 1. Characteristics of the most commonly used green manures/cover crops

Common name	Scientific name	Resistance to shade	Resistance to poor soil	Resistance to drought	N-fixation	Erect or climbing	Annual or perennial	Eaten by humans	Control of weeds	Other uses
Velvetbean	*Mucuna spp.*	3	3	3	140 kg/ha	Climbing	Both	Only with processing	4	Medicine, animal feed
Jackbean	*Canavalia ensiformis*	4	4	4	240 kg/ha	Both	Perennial	Only tender pods	3	None
Lablab bean	*Lablab purpureum* or *Dolichos lablab*	3	1	4	130 kg/ha	Both	Perennial	Yes, pods, green or dry seeds	3	Animal feed, especially dry season
Cowpea	*Vigna unguiculata*	3	3	Some vars. 4	80 kg/ha	Both	Annual	Yes, pods & seeds	3	None
Rice bean	*Vigna umbellata*	3	3	3	80 kg/ha	Both	Perennial	Yes, Very good taste	2	None
Mungbean	*Vigna radiata*	3	2	2?	80 kg/ha	Both	Annual	Yes	2	Bean sprouts, poultry feed
Pigeon pea	*Cajanus cajan*	3	3	4	70+ kg/ha	Erect	Perennial	Yes	2	Animal feed
Tephrosia	*Tephrosia vogelii* or *T. candida*	2	4	4	Nd	Erect	Perennial	No	2	Insecticide
Sunnhemp	*Crotalaria ochroleuca*	3	3	3	Nd	**Erect**	Annual	No	2	Insecticide for stored grains

Source: *Bunch (2005)*
Key: 4 = extremely good, 3 = good, 2 = fair, 1 = poor.

Agroforestry

There is a huge diversity of agro-forestry systems throughout the world, in which the bushes and trees have many benefits. Those with nitrogen-fixing capacity have beneficial effects on plants growing with or after them. Some of this is a result of the fixed nitrogen, but significant quantities can also be supplied in the leaf litter or from deliberate pruning. Trees also improve the microclimate by acting as windbreaks, by improving the water-holding capacity of the soil, and by acting as shade trees for livestock - so focusing the deposition of manure. In the Majjia Valley, Niger, windbreaks of neem trees help to conserve moisture and soil, raising the yields of cereals grown between by some 20%.

On the southern coast of China, there are some 140,000 ha of coastal fields protected by windbreaks and shelter belts. The trees are species of mainly *Casuarina, Metasequoia, Leucaena, Acacia, Paulownia* and various bamboos. These protect crops from typhoon damage in the rainy season and cold spells in early spring and late autumn. As a result, wheat and rice yields can be 10-25% higher than in unprotected zones. *Paulownia* is successfully intercropped with cotton, maize, beans, groundnut, sweet potato, rape, garlic, watermelon and vegetables. *Paulownia* is well suited to agroforestry systems, as its deep tap root does not compete with shallow rooted crops for nutrients and water. A tree can grow 2.5 metres in one year, reaching 10-20 m after 10 years, when it can supply 400 kg of young branches and 30 kg of leaves for fodder or soil amendment.

Woody shrubs and trees planted on the contour can protect the soil and provide fodder, fuelwood and timber. It has long been the practice in the countries of the Mediterranean to plant rows of trees such as olives between rows of cereals or vines. Most recently in tropical countries there has been a considerable research on alley cropping, in which trees of various kinds are planted in contour rows with, usually, subsistence crops in between. Often the trees are fast-growing legumes, which fix nitrogen into the soil. They also provide fodder for animals, green manures and fuelwood. However, much of this research has been conducted on research stations, where the constraints experienced by farmers are not replicated. As a result, very few alley cropping systems have been adopted as designed, and many projects have failed because of the desire to stick to the rigid technical model.

The Sloping Agricultural Land Technology model is one such alley cropping technology being promoted on Mindanao Island in the Philippines. Over the past 20 years, it has been developed on demonstration farms as a highly productive and potentially sustainable system. Contour hedgerows of *Leucaena* are mixed with maize, which yields 3-4 times as much as non-SALT farms, and net returns are better. However, farmers have not as yet been willing to adopt the whole package, and there is little evidence of widespread farmer interest. Some farmers have, however, taken components and adapted them into their own systems.

Many agroforestry systems also combine livestock, so increasing the number of internal linkages. Rubber monocrops can be transformed with the introduction of animals. Although intercrops are cultivated in immature rubber plantations, when the canopy closes only weeds survive. These are costly to control. In Malaysia, sheep rearing in rubber can keep down weeds as well as give added returns from the sheep. Bees and chickens are other animals that will also survive in plantations.

Annex C: Social Capital

From Malthus to Hardin and beyond, analysts and policy makers have widely come to accept that natural resources need to be protected from the destructive, yet apparently rational, actions of people. The compelling logic is that people inevitably harm natural resources as they use them, and more people therefore do more harm. The likelihood of this damage being greater where natural resources are commonly-owned is further increased by suspicions that people tend to free-ride, both by overusing and underinvesting in maintaining resources. As our global numbers have increased, and as incontrovertible evidence of harm to water, land and atmospheric resources has emerged, so the choices seem to be starker. Either we regulate to prevent further harm, in Hardin's words, to engage in mutual coercion mutually-agreed upon, or we press ahead with enclosure and privatisation to increase the likelihood that resources will be more carefully managed.

These concepts have influenced many policy makers and practitioners. They have led, for example, to the popular wilderness myth – that many ecosystems are pristine and have emerged independent of the actions of local people, whether positive or negative. Empty, idle and `natural' environments need protection – both from harmful large-scale developers, loggers and ranchers, as well as from farmers, hunters and gatherers. Since the first national park was set up at Yellowstone in 1872, some 12,750 protected areas of greater than 1000 hectares have been established worldwide. Of the 7322 protected areas in developing countries, where many people rely on wild resources for food, fuel, medicine and feed, 30% covering 6 million km^2 are strictly protected, permitting no use of resources.

The removal of people, often the poorest and the indigenous, from the very resources on which they most rely has a long and troubling history, and has framed much natural resource policy in both developing and industrialised countries. Yet common property resources remain immensely valuable for many people, and exclusion can be costly for them. In India, for example, common resources have been estimated to contribute some US$ 5 billion yr^{-1} to the income of the rural poor.

An important question is: can local people play a positive role in conservation and management of resources? And if so, how best can unfettered private actions be mediated in favour of the common good? Though some communities have long been known to manage common resources such as forests and grazing lands effectively over long periods without external help (8), recent years have seen the emergence of local groups as an effective option instead of strict regulation or enclosure. This `third way' has been shaped by theoretical developments both on governance of the commons and on social capital. These groups are indicating that, given good knowledge about local resources, appropriate institutional, social and economic conditions, and processes that encourage careful deliberation, then communities can work together collectively to use natural resources sustainably over the long-term.

The term social capital captures the idea that social bonds and norms are important for people and communities (Pretty and Ward, 2001; Pretty, 2003). It emerged as a term following detailed analyses of the effects of social cohesion on regional incomes, civil society and life expectancy. As social capital lowers the transaction costs of working together, it facilitates cooperation. People have the confidence to invest in collective activities, knowing that others will also do so. They are also less likely to engage in unfettered private actions with negative outcomes, such as resource degradation. Four features are important: relations of trust; reciprocity and exchanges; common rules, norms and sanctions; connectedness in networks and groups.

Relations of trust lubricate cooperation, and so reduce transaction costs between people. Instead of having to invest in monitoring others, individuals are able to trust them to act as expected, thus saving money and time. But trust takes time to build, and is easily broken. When a society is pervaded by distrust or conflict, cooperative arrangements are unlikely to emerge. Reciprocity increases trust, and refers to simultaneous exchanges of goods and knowledge of roughly equal value, or continuing relationships over time. Reciprocity contributes to the development of long-term obligations between people, which helps in achieving positive environmental outcomes.

Common rules, norms, and sanctions are the mutually-agreed upon or handed-down drivers of behaviour that ensure group interests are complementary with those of individuals. These are sometimes called the rules of the game, and give individuals the confidence to invest in the collective good. Sanctions ensure that those who break the rules know they will be punished. Three types of connectedness (bonding, bridging, and linking) have been identified as important for the networks within, between and beyond communities. Bonding social capital describes the links between people with similar objectives and is manifested in local groups, such as guilds, mutual-aid societies, sports clubs and mothers' groups. Bridging describes the capacity of such groups to make links with others that may have different views, and linking describes the ability of groups to engage with external agencies, either to influence their policies or to draw on useful resources.

But do these ideas work in practice? First, there is evidence that high social capital is associated with improved economic and social well-being. Households with greater connectedness tend to have higher incomes, better health, higher educational achievements, and more constructive links with government. What, then, can be done to develop appropriate forms of social organization that structurally suit natural resource management?

Collective resource management programs that seek to build trust, develop new norms, and help form groups have become increasingly common, and are variously described by the terms community-, participatory-, joint-, decentralised-, and co-management. They have been effective in several sectors, including watershed, forest, irrigation, pest, wildlife, fishery, farmers' research, and micro-finance management. Since the early 1990s, some 400,000-500,000 new local groups were established in varying environmental and social contexts (Pretty and Ward, 2001; Pretty, 2003), mostly evolving to be of similar small size, typically with 20-30 active members, putting total involvement at some 8-15 million households. The majority continue to be successful, and show the inclusive characteristics identified as vital for improving community well-being, and evaluations have confirmed that there are positive ecological and economic outcomes, including for watersheds, forests and pest management.