AGRICULTURAL LAND IMPROVEMENT: AMELIORATION AND RECLAMATION

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Summary

If only every man on his land plot had done everything he can, what a beauty would this world become!

(A. P. Chekhov)

Man keeps his house, and his house is the Earth.

(V. M. Hugo)

Agricultural efficiency depends significantly on the quality of soils, the main source of agricultural productivity. Land improvement (amelioration) became the most important component of peasant labor at the dawn of agricultural development (in ancient Egypt, Greece, Rome, China, etc.). Amelioration differs from the common annual agricultural practices (plowing, harrowing, etc.) in that the effects on the soil can be radical and long lasting. It can be defined as a system of measures for radical improvement of unfavorable hydrologic, soil, and agroclimatic conditions, with a view to the most efficient use of land resources.

Along with the effect on land productivity, amelioration allows us to bring poor and unused land (swamps, wastelands, anthropogenically degraded lands, etc.) into agricultural production, to improve the sanitary state of soils and the environment, and, hence, to raise the living standards and quality of life for people.

The main amelioration practices are engineering reclamation (irrigation, drainage, filling up, flood walls, etc.), chemical, anti-erosion, and agronomic amelioration. Specific methods of land reclamation include the agricultural use of sea and lake bottoms (polders), the development of desert soils, and the improvement of the heat regime of soils (thermal amelioration). Soil amelioration was indispensable over vast areas, with agriculturally unfavorable conditions found in almost all countries. Over thousands of years of the history of land amelioration, experience has been accumulated, the theory of amelioration has been developed, and its methods have been improved. Today, all developed countries have special laws regulating land reclamation policy. The efficiency of amelioration depends on the level of field management.

1. Introduction: Land Improvement—The Basis of Development

I have forced the rivers to flow around my lands, and I have turned their waters to feed these lands that were barren, infertile, and unpopulated before.

(Semiramida)

The nation that destroys its soil destroys itself.

(F. D. Roosevelt)

Efficient and sustainable agriculture is impossible without special measures aimed at improving land quality. Historically, the most significant and wide-scale measures for creation of sustainable agricultural systems were related to irrigation and drainage practices.

Irrigation of farmlands was first practiced by ancient humans after the transition from nomadic to sedentary lifestyles. Ancient Egypt provides an excellent example of well-developed irrigation systems. The lives of ancient Egyptians were closely related to regularly occurring flooding of the Nile river. Even seven to eight thousand years ago, ancient Egyptians used special engineering works to protect their settlements from floods (by creation of thick beds in the foundations of palaces and temples, and embankment of settlements) and to deliver the Nile water to agricultural fields through a network of canals. The construction of large dams and water storage basins on the Nile River dates back to 3000 B.C. The cult of the Nile appeared at the dawn of ancient Egyptian civilization. According to Herodotus and Plutarch, irrigation was considered by ancient Egyptians to be a sacred wedding of the Nile and soil: *Osiridis cum Nephti coitum*. Soil fertility was a matter of worship for them.

Labor-intensive projects for irrigation and drainage favored the consolidation of separate tribes into better organized local societies (nomes) ruled by regional nomarchs; later, the power of nomarchs was diminished by central leaders, and Egypt became the first unified state governed by pharaohs.

The development of irrigation systems in Mesopotamia (between the Euphrates and Tigris rivers), as well as in India and China, also dates back to the third millennium B.C. The first measures of salinization control were applied in Mesopotamia as early as 2400B.C.

Gradually, irrigation and drainage systems that are the most important means of drought, flood, and swamp control became indispensable measures of efficient agriculture in many areas of the world.

Antique and medieval irrigation constructions, such as canals, dams, aqueducts, and sluices, are still preserved in many countries. The history of these constructions has yet to be studied. The most important events were recorded in annals, for example by inscription on papyrus or engraving on memorial stones.

The art of hydraulic engineering and meliorative construction has been perfected by the labor of many generations of scientists and engineers, specialists in different fields of knowledge (from hydraulic engineers, physicists, mathematicians, and civil engineers to modern ecologists and specialists in information science). We should pay tribute to Archimedes, Raphael, Leonardo da Vinci, D. Bernoulli, L. Euler, and many other contributors to the prosperity of modern civilization. It is interesting to trace the progress of irrigation and drainage technologies: from earth to stone and then to high ferroconcrete dams; from a water bucket to windmills and electric pump stations; from spades to powerful machines and sprinklers; from open ditches to closed tile and plastic pipe drainage systems (see “History of land improvement,” EOLSS on-line, 2002).

The role of irrigation and drainage systems in modern agriculture cannot be overestimated. From antiquity to the 1950s, the total area of such improved land had been expanded to 600,000,000 ha. In recent decades, it has been increased to 784 million ha. This is a great accomplishment of modern civilization; the total fund of potential arable land is estimated at 1,392 million ha. In Europe, Asia, and Central America, there are virtually no free land reserves suitable for farming, but vast areas of undeveloped potential arable land exist in Africa (621 million ha) and South America (695 million ha). However, only a small proportion of this land can be used for agriculture without special ameliorative measures. Most of it lies either in extremely dry (e.g. the Sahara) or waterlogged (e.g. the Amazon basin in Brazil) areas.

Irrigated and drained land with artificial regulation of soil water regime represents the most valuable resource of agriculture. This land provides the best opportunities for the most efficient use of water and soil resources.

Irrigation of arable land helps to raise crop yields by a factor of four to twenty, depending on local conditions. Irrigation has converted many initially infertile stony and sandy deserts in Algeria, Tunisia, China, Sudan, Mexico, India, Uzbekistan, and many other countries into flourishing oases.

As at 1995, the Earth's total area of irrigated lands stood at 267 million ha. Of this amount, the largest area (71 million ha, or 27 percent) is in India. The area of irrigated land in China constitutes 48 million ha (18 percent) and in the United States, 25 million ha (9 percent). The total area of drained lands (including land specially protected from floods) reaches 210 million ha. About 28 percent of this area (60,000,000 ha) lies in the United States.

In general, all ameliorated land constitutes about 61 percent of the total area of croplands. Taking into account ameliorated (specially watered) pastures and the farmlands protected from erosion, we can conclude that progress in food production over the last fifty years has been mainly achieved through land amelioration measures. The former UN Secretary-General Boutros Boutros Ghali has stressed that the earth's food problem would be solved if the area of irrigated land could be expanded by 0.5 percent every year.

The further development of irrigation is more limited by the lack of freshwater reserves (except for Brazil, Canada, and Russia) rather than by the lack of potentially suitable land. Indeed, many regions suffer a marked deficit of freshwater.

In this connection, large-scale irrigation projects require comprehensive development of land management strategies with due account for all water users, including cities and settlements, industrial enterprises, agriculture, transport, and recreation facilities.

In 1992, the Earth Summit in Rio de Janeiro adopted the *Agenda 21* program on sustainable development for the next century. It is stressed in this document that the exploitation of water resources should be based on the principle of participation of all interested parties, from local water users to engineers and decision-makers. Water is a valuable economic resource and the cost and benefit of irrigation projects should be thoroughly evaluated before the construction of irrigation systems. Large-scale irrigation systems can provide water to many users, so responsibility for regulation of water distribution and consumption should rest with the society.

In recent years, projects intended to transfer water between different drainage basins have been implemented in many countries. The most impressive projects have been designed in the United States (the Central Valley of California), Pakistan, Iraq, Sudan, Germany, Turkmenistan (from the Amudar'ya River to the Caspian Sea), India, Mexico, and Australia, (see “Water resources for agricultural production,” EOLSS on-line, 2002). In China, a huge project is underway to transfer part of the water from the Yangtze to the Huang He River. The volume of water to be transferred is estimated at 30 km^3 and the length of canals will reach 4,000 km.

In order to combat water deficiency, it is necessary to raise the efficiency of irrigation, to pursue a policy of water economy, to ensure the secondary utilization of drainage and sewage water, and to control the development of secondary salinization of soils in irrigated areas.

Land drainage systems form the basic element of the economy and wealth of many countries, such as the Netherlands, Belgium, Denmark, Finland, Germany, and Belarus. Early drainage systems are still efficiently used in these countries, they are maintained in a good state of repair, and are subjected to necessary regular renovation and reconstruction.

By the second century B.C., people living on the coastal plains periodically flooded by the waters of North Sea, within the territories of modern Netherlands and Germany, had created artificial mounds (terps) on which they could save themselves and their livestock during high floods and surges. Similar mounds can be found in the flood plains of large rivers in the United States and Bangladesh.

In the seventh century A.D., the first sea dikes were constructed, to protect low-lying areas from seawater incursion.

More than one-third of the Netherlands lies below sea level. The land is protected by a system of dikes, dams, canals, and locks supplied with powerful pumps. Earlier, the pumping of water was provided by thousands of windmills.

A classical example of an efficient drainage system is found in south-eastern England, where the first dikes (e.g. the Roman dike) and drainage-ways were built by the Roman invaders. The first law on amelioration of land was adopted in England as early as the twelfth century. Drained lands were considered national property. Experience in drainage of swamps was gained by trial and error.

In the seventeenth century, the sagging of the peat surface led to the waterlogging and inundation of peatlands instead of their drainage. It was suggested that the excess water should be pumped into rivers and the sea with the help of windmills. The drainage system in south-eastern England served as a key site for scientific studies of the most efficient drainage techniques. Thus, optimal parameters of drainage-ways (depth, width, length, etc.) were found.

A special machine for the production of drain tubes from clay was invented. These tubes were applied in many countries for more than a century. Indeed, we can say that modern drainage technology is based on the experience gained in south-eastern England.

It should be mentioned that land amelioration can radically change natural landscapes. Agricultural oases favorable for the life of people are created in deserts and swamps;

water storage basins and canals not only ensure the water supply of people and serve as the basis for industrial and agricultural development of vast areas, but they can also become important habitats for wildlife. Grand hydraulic engineering constructions built of stone and concrete, numerous water lifts and pumps (including windmills) can make the scenery more diverse and interesting, enhancing the aesthetic value of the landscape.

In recent decades, new methods of land amelioration have been developed. Their emergence is related to the need to minimize the negative consequences of anthropogenic impacts on land and water resources, as well as on nature in general. These are the measures of erosion and deflation control, waterlogging and inundation control, soil pollution control, and so on. Together with the traditional methods of amelioration, they form the basis of sustainable development of modern society. Integrated amelioration methods can be called multiple amelioration.

Multiple ameliorative procedures are a vital element of modern farming systems as they raise the fertility of soils and ensure high and stable yields. At present, sustainable agriculture assumes the creation of purposefully managed agro-landscapes. The sustainability of farmland is ensured by the purposeful control of soil, hydrological, biochemical, and other processes taking place in these landscapes. The main goal of control measures is to regulate energy and matter fluxes in agro-landscapes and to minimize their unproductive losses.

The land reclamation worker and the land manager are the architects of agro-landscapes. The design of agro-landscapes should be adjusted to local environmental conditions. On the basis of long-term experience, scientists have developed optimal methods and technical means of land amelioration for different natural zones. Each amelioration project should take into account zonal peculiarities of amelioration procedures and the specific features of the local environment.

There have been very serious controversies concerning optimal land use in certain areas. Often, it is difficult or impossible to satisfy the interests of all parties, for example, those concerned with agriculture, wildlife, landscape planning, recreation, and so on.

Irrigation, drainage, and other ameliorative systems include not only land areas but also rivers, lakes, and other water bodies that serve as water sources for irrigation or water collectors for drainage networks. Often, it is necessary to create artificial water storage basins and pump stations on these water reservoirs.

Dikes and artificial levees are built along water courses to protect neighboring lands from floods. Sometimes, river beds are deepened and straightened. To provide the infrastructure and necessary means of transportation, irrigation and drainage systems are also supplied with a network of roads, power supply lines, communication lines, technical buildings, and houses. This infrastructure is an obligatory component of modern large-scale ameliorative systems.

While solving economic and social problems, amelioration can have very serious impacts on the environment, especially on land and water resources, vegetation, and fauna. To a lesser extent, it affects subsurface conditions and the atmosphere.

Amelioration can change the life conditions of humans, but the problems of environmental protection and intelligent use of natural resources in ameliorated areas deserve special consideration.

Negative consequences of large-scale amelioration projects may be very serious and lead to a complete devastation of land. The most serious hazards are the secondary salinization and waterlogging of irrigated lands, mineralization of peat accompanied by surface subsidence, peat fires, erosion and deflation of soils, a decrease in the productivity of fish resources, and soil and water pollution. (see "Soil degradation," EOLSS on-line, 2002). The preservation of biodiversity is a fundamental principle of modern amelioration (see "Sustainability of agriculture," EOLSS on-line, 2002).

An important conclusion was made during the International Congress on Irrigation and Drainage (The Hague, the Netherlands, 1993): in the twenty-first century, irrigation and drainage will remain the only means of sustainable agricultural production ensuring the solution of the food supply problem in developing countries. This statement is of primary importance. It should be taken into account while elaborating national laws and programs on food security in many countries.

Meanwhile, it is often criticized by the Greens and those who call themselves "lovers of nature." They argue that, in 1985, the privileges given to the farmers developing waterlogged areas were cancelled in the United States. A ten-year long program on the conservation of wetlands and conversion of a part of previously drained lands into wetlands was adopted. In 1992, the thirty-year long program for wetland conservation was accepted. According to it, nearly 1 million ha of drained bogs used in agriculture had to be redeemed by the government for conversion into recreation lands. The propaganda campaign in favor of this program was very strong. The execution of this program is considered a matter of national importance and a patriotic duty of farmers. Indeed, this program is very important for the United States.

However, it should be mentioned that during the previous two centuries, virtually all wetlands (more than 60 million ha) have been drained and converted to farmlands in the United States. At present, the reserves of free land for the creation of recreation zones around large industrial centers are minimal. Meanwhile, the need in such recreation areas is very high.

A similar program was adopted in the Netherlands. But this does not mean that the use of drained lands in agriculture is inefficient and unfeasible from the economic point of view. In fact, the redeemed lands in the United States are mostly lands that have been drained after 1985. Most of them belong to the category of weakly cultivated (improved) lands. At the same time, lands drained many years ago with high inputs of manure, fertilizers, and soil amendments constitute the golden fund of American agriculture.

The problems of ecological safety of land amelioration and the creation of highly productive and sustainable agro-landscapes, ensuring the sustainable development of modern civilization, are the focus of attention of scientists and specialists in agriculture and land management. There is no doubt that their significance in the twenty-first century will increase even more.

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Biographical Sketch

Boris Stepanovich Maslov was born in 1929 in Moscow oblast (Russia). He is a Doctor of Technical Sciences (1976), Professor (1979), Academician of the Russian Academy of Agricultural Sciences (1991), Honored Worker of Science and Technology of the Russian Federation (1994), Prize Winner of

Council of Ministers of the USSR (1981), and Laureate of the A. N. Kostyakov Gold Medal (1993). His work in amelioration science was acknowledged by the jubilee diploma and medal of the ICID.

He graduated from the Moscow Institute of Hydraulic Engineering and Water Management (1954) with a diploma in hydraulic engineering. In 1965, he took training courses at the University of California.

He worked as the head of the Science Department of the Ministry of Melioration and Water Management of the USSR (1975–85); director of the A. N. Kostyakov Research Institute of Hydraulic Engineering and Melioration (1985–8); and the head of the Department of Melioration and Water Management of the RAAS (1991–9). In 2000, he was appointed the Senior Specialist of the Engineering and Production Center on Water Management, Melioration, and Ecology.

Professor Maslov's scientific interests encompass various aspects of land drainage and irrigation, reclamation hydrogeology, environmental conservation aspects of land reclamation, and the history of soil amelioration.

Professor Maslov is the author of more than 500 published works, including forty monographs, on soil reclamation, meliorative hydrogeology, environmental protection issues related to land reclamation works, and the history of amelioration science.

He participated in the work of the International Commission on Irrigation and Drainage (ICID), International Peat Society (IPS), and the Society of Agricultural Engineers, among others.