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Twenty-first century. Innovative approaches to the development of agriculture in the Asian countries

In the second decade of the 21st century international agricultural organizations, including FAO, have understood that approaches to innovative development of agriculture in the countries of the East are fundamentally different from scientific developments in the West.

In the mid-twentieth century, Norman Borlaug, known as the founder of the "green revolution" (GR), developed new high-yielding varieties (HYV) of grain crops for each agricultural zone, but many of the soil cultivation technology has been standardized and transferred from the developed countries of the West. The GR technology was based on new HYV crops, irrigation, application of chemicals (the use of mineral fertilizers and pesticides) and small mechanization. The success of GR led to the transition of agriculture in the developing Eastern countries to a new stage. Production of cereals has increased by 4.5 times, yield – 3.5 times, and the population – 2.5 times in Asia throughout the period of GR (1961–2014) [8].

However, the return from technology adoption GR is gradually reduced. The growth rate of grain production and yield in the first quarter-century of GR are much higher than those in subsequent years. There still are reserves for growth in crop production in countries of the East, but mainly due to optimization (rather than increased) production resources. Further development of the technologies of the «green revolution» will cause the destruction of agricultural ecological system of the Asian countries [6].

The introduction of HYV and appropriate technologies for their cultivation resulted in: a) loss of genetic diversity, 2) soil degradation, 3) the depletion of groundwater, 4) nitrate pollution of water bodies, 5) the increase in emissions of greenhouse gases. For example, the emissions associated with agriculture have doubled for the period GR and amount to 25 per cent of total emissions. The contribution to these processes makes the production of grain (especially rice-paddy which is a major consumer of mineral fertilizers), and livestock is responsible for half of all methane emissions. That is, an increase of mineral fertilizers and pesticides use in India and other countries should not grow anymore.

The green revolution has made a great contribution to providing the food security of developing countries and to the reduction of the undernourished population [5]. However, the reduction in the proportion of undernourished people amounted to 33 per cent, and the absolute number of undernourished

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decreased by only 13 per cent from 1990 to 2014 according to FAO estimates [8]. The demand for grain will increase in the minimum estimate by 45 per cent from 2014 to 2050.

If in the early 21st century in order to improve the efficiency of agriculture in Japan FAO suggested to increase the size of farms and to introduce labor-saving systems; after 10 years, the focus has changed to the use of resource-saving technologies that will ensure sustainable agriculture in Asia.

FAO proposed a model of sustainable development of agriculture «Save and Grow» in 2011. «Save and Grow» farming systems are based on five complementary components and their related practices [2]:

1. Agro-environmental innovations and climate optimized agriculture;
2. Agricultural biotechnology;
3. Green employment;
4. ICT-technologies in agriculture;
5. Small-scale mechanization in agriculture.

1. **Agro-environmental innovations and climate optimized agriculture** is based on the following foundations:

– *Conservation agriculture*, through minimal soil disturbance, the use of surface mulches and crop rotation, and the integrated production of crops, trees and animals;
– *Healthy soil*, through integrated soil nutrition management, which enhances crop growth, bolsters stress tolerance and promotes higher input-use efficiency;
– *Improved crops and varieties* adapted to smallholder farming systems, with high yield potential, resistance to biotic and abiotic stresses and higher nutritional quality;
– *Efficient water management* that obtains 'more crop per drop', improves labor and energy-use efficiency, and helps reduce agricultural water pollution; and
– *Integrated pest management* based on good farming practices, more resistant varieties, natural enemies, and judicious use of relatively safer pesticides when necessary.

Here are a few successful complex agricultural systems in developing countries [6].

Crop/Livestock. "Push-pull" fights pests, boosts milk production. "Push-pull" is the basis of an integrated crop/livestock production system which does not require high levels of external inputs. It harnesses complex chemical interactions that destroy stem borer larvae and inhibit the growth of Striga weed. The system provides year-round soil cover, helps conserve soil moisture and soil structure, and prevents erosion. Farmers have adapted "push-pull" to allow intercropping with beans and report that their maize yields have increased three to four times. High quality fodder produced by the system helped 700 to farmers increase milk production by 1 million liters a year [6].

Wheat/Rice. Zero-tillage direct-seeding raises wheat yields while reducing water and fuel costs. Alternate wetting and drying of rice fields results in water savings of 30 to 50 percent. After precision land-levelling, farmers need 40 per cent less water, use less fertilizer, and harvest more grain. "Needs-based" nitrogen management cuts fertilizer applications by 25 percent with no reduction in yield. Clover grown in rotation suppresses weeds that might otherwise infest subsequent cereal crops. Adoption of direct-seeding has been facilitated the ready availability of seed drills developed by the private sector [6].

Rice/Maize. High yielding hybrids help adapt to climate change. By shifting from rice to maize during the dry season, farmers save groundwater from over-exploitation. Growing dry season maize costs more than other cereals, but economic returns are 2.4 times higher. Farmers trained in resource-conserving crop management obtain maize yields that are twice the national average. Farmers have cut fertilizer applications using poultry manure, and grow legumes to reduce nitrate pollution of aquifers. Establishing rice and maize on untilled permanent beds produces higher yields, using 38 percent less water. Drill-seeded rice yields are like those of transplanted rice, but require less water and labor [6].

Wheat/Legumes. The extra benefits of legumes-before-wheat. Plant residues from forage legumes add to the soil up to 300 kg of nitrogen per ha. Chickpeas and pigeon peas secrete organic acids that facilitate wheat's access to soil phosphorous. Wheat grown after legumes produces higher grain yield with higher protein content. In Ethiopia, rotating fava beans and wheat produced 77 percent more wheat grain while reducing fertilizer applications. Short-duration legume varieties grown in summer enhance soil fertility and increase water-use efficiency. Zero-tillage and surface residues help realize the full benefits of legume rotations [6].

Maize/Legume. Traditional system makes more productive use of land. Maize-legume systems usually produce less maize than monoculture, but provide higher economic returns. Generally, rotations provide better yields and higher profits than maize-legume intercropping. Higher land productivity makes maize-legume systems especially suitable for smallholders. One hectare of soybeans fixes 22 kg of nitrogen, produces 2.5 tons of forage, and reduces Striga infestations. Under conservation agriculture, the highest yields are achieved when maize is rotated with legumes. Climate change mitigation funding would encourage smallholder adoption [6].

Maize/Forest. Where trees and shrubs cost less than fertilizer. Maize agroforestry is practiced on 300000 ha in Zambia and half a million farms in Malawi. By keeping native 'fertilizer trees' in their fields, farmers have boosted maize yields by as much as 400 per cent. Leguminous trees and shrubs add from 100 to 250 kg of nitrogen per ha to the soil in two to three years. Growing maize with leguminous shrubs generates higher net returns than growing maize with subsidized mineral fertilizer. The system uses water more efficiently and is more resilient to drought. Agroforestry provides fuelwood and fodder, improves water filtration and sequesters carbon [6].

Maize/Livestock. 'Nutrient pumps' feed cattle, nourish maize. Zero-tillage, organic soil cover, crop rotation and improved pastures underpin integrated crop and livestock systems. A key component of maize-livestock systems is Brachiaria grass, which restores soil structure and is far more nourishing than native vegetation. Mulch-based, direct-seeding cropping systems grow three cereal crops a year, intercropped with forage species. In Brazil, more than 4 million ha are under direct-seeding, which has replaced inefficient, tillage-based soybean monoculture. Relay cropping Brachiaria with maize reduces intercrop competition, leading to optimal use of land resources and less land degradation [6].

"Slash-and-mulch" cultivates beans and maize on untilled soil enriched with tree prunings. The system builds up soil nutrient stocks, and produces maize yields double those of traditional shifting cultivation. It reduces the time needed for land preparation, prevents soil erosion, and improves the supply and quality of water for downstream consumers. Many 'slash-and-mulch' farmers have diversified production, primarily into home gardens and livestock. The system enhances ecosystem services, including carbon sequestration, and reduces methane emissions. It is a promising alternative to slash-and-burn agriculture for sub humid hillside areas of the tropics [6].

Rice-paddy/Aquaculture. A richer harvest from paddy fields. A one-hectare paddy can produce up to 9 tons of rice and 750 kg of fish a year. Fish raised with rice provide protein, essential fatty acids and a wide range of micronutrients. Fish are biological control agents for weeds, insect pests and vectors of serious diseases, such as mosquitoes. High yields, fish sales and savings on inputs produce the income up to 400 percent higher than income from rice monoculture. In China, rice field aquaculture production reached more than 1.2 million tons. The Indonesian Government has launched a "one-million hectare rice-fish program" [6].

2. **Agricultural biotechnology.** On the wave of negative attitudes to genetic engineering are not considered that most of the biotechnological methods used for the strengthening and more effective use of genetic resources [4].

Reproductive technologies have the potential to conserve livestock, fish by reducing disease and more efficient production through selection of the sex of the embryo, and synchronization of ovulation.

Molecular markers shorten the time of plant selection and increase its accuracy. This method is used to improve old varieties and develop new varieties of plants.

Tissue culturing method – this quick and inexpensive method of mass reproduction by cloning, disease-resistant varieties of rice, used in more than 30 African countries.

Chromosome engineering has a wide range of applications in agriculture: production of sterile varieties of plants and fish, the acceleration of selection without breaking the main characteristics of the fetus.

Mutagenesis is one of the few biotechnological methods, which is mostly used in developing countries to accelerate spontaneous mutations and new phenotypes.

Genetic engineering is designed to create genetic modified (GM) crops. In 2010 GM crops were grown on 134 million hectares in 16 developing countries, particularly in China, GM trees are grown on 400 ha.

3. **"Green" employment** is one of the sides of "green" economy that will allow developing countries to shift to environmentally friendly agriculture. It is assumed that only bioenergy and related production in developing countries can give additional work to 12 million people [2]

4. **ICTs in agriculture** are applied in two ways: first, directly in the production to control the exact processes of growing plants and livestock production; secondly, in the sphere of organization of production, accounting systems and sales [1].

5. **Small-scale mechanization** in agriculture is used only in the countries of the East. The capital is invested, not in funds, saving labor (tractors, seeders, harvesters), and mechanisms that improve soil fertility (pumps, wells, plants, shredders, mowers, cultivators, etc.)._

An overview of new approaches to the development of agriculture in the East clearly indicates the turn to resource-saving systems.

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