Section 10

Science and Innovations

10.1. Innovations in 2017

Drones and robots are improving water management

Drones enable control of water use even in the more inaccessible regions of Thailand, where water shortage is linked not only with excessive agricultural water use but also with drought as a result of climate change. Aerial photographs support monitoring of water resources (siltation, erosion) and are used for the 3D models that enable experts to simulate the effectiveness of planned conservation measures. The experts use such models to rapidly recreate different weather scenarios, climate developments and impacts[9].

The Canadian company Deep Trekker developed an underwater drone system DTG2 ROV to explore underwater parts of the hydraulic facilities. This helps to escape expensive inspection by divers. DTG2 ROV may be deployed for four-sided control over operation of underwater parts of dams, pumping stations, and various water intakes[10].

The International program of agricultural robotics "Ural Cognitive Agro" is launched by Cognitive Technologies Group (a Russian developer of artificial intelligence system for drones) and the Ural Federal University. The Program seeks to develop artificial intelligence technologies and hardware-based solutions for robot-aided agriculture (sensors and calculators) and create ground- and air-based robotic systems. According to international analysts, application of agricultural robotics would increase efficiency of business processes by 50-70% through reduced inputs of fuel and decreased water and energy losses, improve harvesting due to lower losses of crops (to 60-80%) and optimization of main work flows, increase crop yields 1.5-2 times and reduce the cost of planting by 80%[11].

Farmers may be substituted by "speaking" tractor robots, which could help address problems related to ageing of rural population in Japan. In the future, tractor robots will be connected to GPS system and will be able to work at any time and under any weather conditions, even when their owners sleep[12].

The **fully automated innovation tractor** was developed. It uses the Global Navigation Satellite System (GNSS), gyroscopes, camera, and computer. The tractor developed by a Laboratory of the Illinois University leaves the agricultural machinery barn, conducts preset operations and returns to the barn without human intervention. Combination of GNSS and other tractor location sensors, including telematics, enables innovation tractors to navigate in the field. The farmer may observe the process through the camera[13].

In Poland, a new affordable sorting machine was invented. GreenSort is an innovative sorting machine designed especially for small farms and growers, with 5 to 20 ha orchards. The innovative sorting machine is equipped with camera, which allows it to precisely measure the diameter, sort by color and detect visual damages. It has simple design and construction, relatively small size. Fruits are moved practically without pulling away from the surface on which they travel. This minimizes the potential risk of damage during sorting. At the same time, price starts from approximately €14,000[14].

Intra-row weeding possible with vision systems. Researchers of Wageningen University & Research Center developed weeding machines which are able to do intra-row weeding. The intra-row weeding machines are based on vision systems which detect the weeds in the crop. The machine allows extracting data on weed pressure, harvest moment and nutrient shortage. Data will be represented as heat maps to the grower, which can be viewed in all main farm management systems. By structuring the data in a user friendly way, the grower will be supported to make choices to grow its crops more efficiently[15].

[9] http://reliefweb.int/report/thailand/drones-are-improving-water-management-thailand
[10] *World Water Journal, volume 40, June 3, 2017*
[11] www.kazakh-zerno.kz/novosti/mirovoj-rynok-selskogo-khozyajstva-i-prodovolstviya/237277-v-rossii-zapuskayut-proekt-po-robotizatsii-selskogo-khozyajstva (in Russian)
[12] www.kazakh-zerno.kz/novosti/mirovoj-rynok-selskogo-khozyajstva-i-prodovolstviya/239622-fermerov-smogut-zamenit-govoryashchie-roboty-traktory-premer-ministr-yaponii (in Russian)
[13] www.agroxxi.ru/selhoztehnika/novosti/fermer-sobiraetsja-upravljat-traktorom-iz-kuhni.html
[14] www.agroxxi.ru/selhoztehnika/novosti/v-polshe-pojavilos-novoe-sortirovochnoe-oborudovanie-dostupnoe-lyubomu-sadovodu.html
[15] www.agroxxi.ru/selhoztehnika/novosti/vnutrirjadnaja-propolka-teper-vozmozhna-pri-pomoschi-robotov.html

Alternative Energy in Agriculture

The Department of Agriculture of Philippines plans to set up **solar-powered irrigation systems** nationwide to improve rice production. Each system would pump up 400-1,000 gallons of water a day[16].

In the Punjab province (Pakistan), a project is implemented to improve water productivity and increase water availability through **provision of climate smart technology**. Particularly, interventions envisaged under the proposed project would entail promotion of hi-tech technologies including solar system and tunnel technology for enhancing crop yields and alleviating poverty in the province[17].

Agrophotovoltaics increases the land use efficiency by over 60 percent. Until now, acreage was designated for either photovoltaics or photosynthesis, that is, to generate electricity or grow crops. An agrophotovoltaics (APV) pilot project near Lake Constance, however, has now demonstrated that both uses are compatible. For one year, the largest APV system in Germany is being tested on the Demeter farm cooperative Heggelbach. In the demonstration project "Agrophotovoltaic -- Resource Efficient Land Use" (APV-Resola)" led by the Fraunhofer Institute for Solar Energy Systems ISE, solar modules for electricity production are installed directly above crops covering an area of one third hectare. Winter wheat, potatoes, celeriac and clover grass were the first crops to be tested. The south-west orientation and the extra distance between the five meter high rows of bifacial glass-glass PV modules ensured that the crops were exposed to uniform solar radiation. The results from the first harvest were, for the most part, promising. "The crop yield of clover grass under the PV array was only 5.3 percent less than the reference plot," reports Prof. Petera Högy, agricultural expert at the University of Hohenheim. The yield losses for potatoes, wheat and celeriac are between 18 to 19 percent and therefore somewhat higher." About 40 percent of the electricity produced on the farm was used directly to charge the electric vehicles and process the harvested crops. In the future, farmers want to further optimize consumption and use the energy generated to self-supply up to 70% with the help of an energy storage system. Overall, the dual use of space increased the efficiency of land use by 60%[18].

The Dutch company SunGlacier has created a new solar powered device to collect the water in the middle of the hottest, driest places on the planet such as the Sahara desert. The device is dubbed the Desert Twins, and the company refers to it as an "artificial water well". It uses a process of condensation to collect and create water out of the air. The harvester is made out of two separate devices, one of which is an energy unit that allows the device to generate and store power from solar cells. The other device is a water maker which uses the stored energy to cool down a metal plate and begin the process of condensation[19].

At the Los Angeles Auto Show, **Toyota has announced it will build the world's first megawatt-scale carbonate fuel cell power generation plant** with a hydrogen fueling station in California. This 'Tri-Gen" facility will use locally-sourced agricultural bio-waste to generate huge amounts of power, lots of hydrogen, and clean water. Yes, that probably means cow poop. The plant is scheduled to go online in 2020 and will generate approximately 2.5 megawatts of electricity, which is equivalent to the amount used by 2,350 average homes in the region. Additionally, the plant will generate 2.35 MW of electricity and produce 1.2 tons of hydrogen every day, which is enough to power about 1,500 vehicles on an average daily drive[20].

SolarGaps blinds collect solar energy. The idea of developers is to expand the function of ordinary blinds. SolarGaps not only darken the room but also collect sunshine converting it into energy. The developers guarantee that the smart blinds automatically track the sun throughout the day. This will allow reducing energy bills by up to 70%[21].

Agricultural Innovations – Irrigation to Floating Farms

The Spanish company Expanhouse developed **an irrigation system that can save up to 50% of water** and fertilizer compared to traditional drip irrigation. The project consists in the use of small

[16] http://www.sunstar.com.ph/2017/02/07/solar-powered-irrigation-system-be-replicated-nationwide-524505
[17] http://dailytimes.com.pk/punjab/19-Feb-17/solar-based-agriculture-may-help-enhance-crop-yields
[18] www.agroxxi.ru/mirovye-agronovosti/agrofotovoltanika-povyshaet-rentabelnost-selhozbiznesa-na-60.html
[19] http://carawan-net.org/node/1280
[20] https://rtr.md/novosti/raznoe/novaya-elektrostanciya-ot-toyota-budet-rabotat-na-navoze
[21] http://ekois.net/solargaps-zhalyuzi-dlya-sbora-solnechnoj-energii/#more-22825 (in Russian)

deposits of porous ceramic material buried next to the roots, which release the water as the plants require it. The immediate advantages of the system are the elimination of evaporation and infiltration in the soil, almost reducing them to zero. As a result, the soil surface remains dry and the impact of pests and weeds is reduced, which entails savings in labour, pesticides and herbicides. The roots have the water they need at all times, thus preventing moments of excessive or deficient irrigation. The system is self-regulated, without the need for a large investment in sensors or other technologies, and the deposits can be connected to existing drip networks in order to minimize installation costs. Fertirrigation (technique through which irrigation is combined with fertilization) and smart irrigation will lead to a significant saving of water, nutrients and energy in the farms thanks to the improvement in the efficiency of their use[22].

In Tamera, Portugal, the permaculture system was implemented successfully[23]. The project's goal was to retain all the rainwater that falls on the land to refill the groundwater which was getting lower each year. The lakes were dug out and formed without any concrete seal at the bottom so water can seep into the earth. There's a principle in permaculture called the triple S – slow, spread and sink. The Tamera case study was presented at the UN's COP22 in Marrakech. The key to ecosystem restoration is rainwater and vegetation management[24].

The Centre for Ecological Security in cooperation with the experts from research center of the Kazakh-American Free University planted trees using new technologies. They used water-retaining hydrogel, one gram of which may absorb 200-250 milliliter of water. Acclimatization of plants with the help of hydrogel was assessed by ecologists in spring[25].

Chinese crack 'game-changing tech' turning desert into farmable land. Scientists in China claim to have invented breakthrough technology that can convert desert sand into fertile soil. In just six months, researchers at Chongqing Jiaotong University were able to transform 200 hectares of an arid inner Mongolian desert into a green pasture of cultivated crops. The secret to their remarkable success is a special paste made of a substance which is found in plant cell walls. When mixed with sand, the paste is able to retain water, nutrients and air. Crops including corn, tomatoes, sorghum and sunflowers are thriving in the once hostile environment, according to Zhao Chaohua, Associate Professor of Chongqing Jiaotong University. "According to our calculation, there are over 70 kinds of crops growing here. Many are not planted by us but they just grow themselves," said Chaohua. The research team has big future plans. This fall, it hopes to transform an additional 200 hectares of desert – and possibly more than 13,000 in the next few years[26].

Japan develops new methods of growing agricultural products: instead of soil polymer film is used where plants take their roots. Initially developed as a permeable membrane for building an artificial kidney, the film allows growing crops in desert and other places, which have no suitable soil. The technology enables easy control over plants nutrition. Even those who have no special education may be involved in agriculture using it. It is also used to produce innovative containers, which as high as possible hinder the process of oxidation of food and drinks[27].

Chinese scientists develop rice that can grow in seawater, potentially creating enough food for 200 million people. The rice was grown in a field near the Yellow Sea coastal city of Qingdao in China's eastern Shandong province. 200 different types of the grain were planted to investigate which would grow best in salty conditions. Sea water was pumped into the fields, diluted and then channeled into the rice paddies. The scientists expected to produce 4.5 tons of rice per hectare but the crops exceeded expectations, in one case delivering up to 9.3 tons per hectare. There are one million square kilometers of land in China where crops do not grow because of high salinity. Scientists hope the development of the new rice will allow some of these areas to be used for agriculture. If even a tenth of these areas were planted with rice, they could

[22] http://www.freshplaza.com/article/171358/Spanish-project-for-smart-irrigation-praised-by-international-jury

[23] **Permaculture** is a system of agricultural and social design principles centered on simulating or directly utilizing the patterns and features observed in natural ecosystems. The word permaculture originally referred to "permanent agriculture" but was expanded to stand also for "permanent culture", as it was understood that social aspects were integral to a truly sustainable system. It has many branches that include, but are not limited to, ecological design, ecological engineering, environmental design, and construction.

[24] https://www.theguardian.com/global-development-professionals-network/2017/mar/07/tamera-portugal-permaculture-water

[25] http://www.inform.kz/ru/novye-tehnologii-pri-posadke-derev-ev-primenyayut-v-vostochnom-kazahstane_a3021782 (in Russian)

[26] https://tech.onliner.by/2017/09/19/sand

[27] http://kvedomosti.ru/news/v-yaponii-razrabotali-chudo-plenku-kotoraya-sovershit-perevorot-v-selskom-xozyajstve.html (in Russian)

produce 50 million tons of food – enough to feed 200 million people and boost China's rice production by 20 per cent. The saltwater rice is currently on sale for around 50 yuan (£6) per kilogram – around eight times more than ordinary rice. Despite the cost, six tons of the grain have already been sold, with consumers praising its flavor and texture. The rice is also thought to have several health benefits, including being high in calcium[28].

UAE's first vertical farm opens in Dubai. Based in Al Quoz Dubai, Badia Farms uses innovative commercial hydroponic technology to grow micro-greens and baby leaf herbs without sunlight, soil or pesticides[29].

In Mexico, a trial has produced raspberries in a commercial berry operation in a greenhouse with an automatic retractable roof. The raspberries are planted in a retractable roof house. They get wet during rains, since the roof covering is water porous, and are being pollinated naturally by native bees. This technology has increased development of fruiting laterals. They have virtually no problems due to spotted mite or spotted wing drosophila, including fewer problems with rust than those in the tunnels even though the retractable flat roof is allowing the frequent summer rains to fall on the crops[30].

The recent development of advanced multi-layer mulch films produced in Israel at Ginegar Plasticshas brought significant advantages for farmers worldwide. Films with different combinations of layers, thicknesses and widths as well as coatingshave various properties to suit specific growers' needs, specifications and crops[31].

Joanne Chory, a Californian plant biologist and geneticist, intends to develop a **super plant that will both provide food and store carbon dioxide in its roots**. A "super chickpea plant" now in development could remove huge amounts of excess atmospheric carbon dioxide and fix it in the soil, greatly diminishing the impacts of climate change. Ultimately, Chory's goal is to breed plants that grow extra-deep roots with lots of suberin for long-term carbon storage. Chory estimates that developing a super plant in this fashion would take around 10 years and $50 million. She estimates that if 5 percent of the world's cropland, approximately the total area of Egypt, were devoted to such super plants, they could capture about 50 percent of current global carbon dioxide emissions[32].

Underground London farm uses WWII bomb shelter. At 7,000 square feet, the tunnels are used to host trays upon trays of sprouting herbs. Childhood friends and founders Steven Dring and Richard Ballard had a simple idea – find a solution to the way that we, often arduously, source our food. About twenty different types of herb are being cultivated in the former bomb shelters, including pea shoots, rocket, red mustard, pink stem radish, garlic chives, fennel and coriander. The plants are being supplied to markets and wholesalers right across London. The Growing Underground uses hydroponics, a system whereby plants are grown without soil but with the help of low-energy LED lights. This allows each crop to grow in a carefully controlled, pest-free environment[33].

The Spanish design company proposed the concept of Smart Floating Farm (SFF) in case of global food deficit. The company envisions that the triple-decker Smart Floating Farms would feature 2.2 million square feet of fish farms, a hydroponic garden, and solar panels on the roof. The goal of these water-bound farms is to bring sustainable food resources to parts of the world that need it most[34].

Wastewater Treatment and Desalination

Wastewater is a depository of useful substances. Designed and developed by a team of engineers from the University of South Florida (USF), the NEWgenerator processes waste to produce three different resources. By hooking it up to existing toilet blocks, the system also removes the need for the facilities to be connected to sewage systems. First, the waste is fed into a bioreactor, where anaerobic microorganisms break down the solids and produce biogas. This process is done without the need for chemicals or aeration equipment, and the methane created can be harvested for use

[28] www.independent.co.uk/news/rice-seawater-chinese-scientists-food-200-million-a8017971.html
[29] www.agroxxi.ru/zhurnal-agromir-xxi/novosti/pervaja-vertikalnaja-ferma-v-oaye-pohvastalas-urozhaem-mikro-zeleni.html
[30] www.agroxxi.ru/zhurnal-agromir-xxi/novosti/v-meksike-testiruyut-teplicu-s-razdvizhnoi-kryshei-dlja-vyraschivanija-maliny.html
[31] www.israelagri.com/?CategoryID=402&ArticleID=1454
[32] www.agroxxi.ru/zhurnal-agroxxi/novosti-nauki/superrastenie-spaset-ot-goloda-i-klimaticheskih-izmenenii.html
[33] http://kvedomosti.ru/news/podzemnaya-ferma-vyrashhivanie-rastenij-na-glubine-33-metrov.html
[34] www.agroxxi.ru/zhurnal-agroxxi/novosti-nauki/plavuchie-fermy-pomogut-vyzhit-chelovechestvu-v-kataklizmah.html

in cooking, heating or electricity production. Then, the liquid waste moves into another chamber, where a fine-pore microscopic membrane filter removes bacteria, viruses and any remaining solid particles. The water that passes through is then disinfected with chlorine, and while the end result is probably still not drinkable, it's clean enough to use to flush the toilets in the block or irrigate crops. And finally, the solid waste can be recovered for its nutrients, including nitrogen and phosphorus, and used to fertilize crops and gardens. The first generation of the NEWgenerator was installed for communities in India in 2016. Units will soon be installed in South Africa.

Plenty of past projects have tried to clean up the sewage situation in developing countries. The Loowatt turns human waste into biogas and fertilizer, a Bristol team fitted a urinal with a microbial fuel cell to produce "pee power," and the Nano Membrane Toilet is a waterless design that burns solid waste to produce fertilizer and electricity[35].

Engineers at the University of California, Riverside have developed a new way to recover almost 100 percent of water from highly concentrated salt solutions. The system will alleviate water shortages in arid regions and reduce concerns surrounding high salinity brine disposal, such as hydraulic fracturing waste. While reverse osmosis is the most common method of removing salt from seawater, wastewater, and brackish water, it is not capable of treating highly concentrated salt solutions. One way to treat brine is membrane distillation, a thermal desalination technology in which heat drives water vapor across a membrane, allowing further water recovery while the salt stays behind. However, hot brines are highly corrosive, making the heat exchangers and other system elements expensive in traditional membrane distillation systems. Furthermore, because the process relies on the heat capacity of water, single pass recoveries are quite low (less than 10 percent), leading to complicated heat management requirements. To improve on this, the researchers developed a self-heating carbon nanotube-based membrane that only heats the brine at the membrane surface[36].

Information Dissemination

Using data from NASA, Pakistan's water research agency is sending rain forecasts to 10,000 farmers, helping them to irrigate more efficiently and increase their crop yields. The text messages (or SMS) are sent by the Pakistan Council of Research in Water Resources (PCRWR), a government agency that carries out water research. Weekly information to farmers through text messages tells them how much water their crops need and sends them weather forecasts[37].

Other innovations

India unveils anti-smog cannon in fight against Delhi pollution. The cannon blasts water droplets at high speed to flush out air pollutants. The cannon – designed to combat dust on mining and construction sites – costs roughly $31,000[38].

By 2020, scientists from the Climate and Environmental Physics Laboratory of the Ural Federal University named after B. N. Yeltsin in cooperation with colleagues from several institutes of the Russian Academy of Sciences, as well as from France, Germany, and Japan will develop a **verification model, which will forecast climate change in the Russian Arctic zone in the nearest 50 years**. Research is based on monitoring network of isotopic tracer of water cycle. The ultimate goal is to provide accurate data on how the climate will change in the nearest decades in the Siberia's Arctic zone: how the surface temperature, rainfall pattern, and temperature in the permafrost at depths down to 7 meters will change[39].

[35] www.ecocommunity.ru/news.php?id=37832
[36] http://uznature.uz/?q=ru/node/2980
[37] www.eco-business.com/news/satellites-and-sms-help-pakistans-farmers-with-smart-irrigation/
[38] https://politros.com/society/107474/
[39] https://www.znak.com/2017-02-20/vosem_regionov_rossii_riskuyut_uyti_pod_vodu_cherez_50_let_prognoz_uralskih_uchenyh (in Russian)

10.2. An Interactive Map of Best Practices on Water, Land and Energy Use and Environmental Protection in Central Asia

In 2017, an interactive map of best practices on water, land and energy use and environmental protection in Central Asia was developed. This online resource contains information on successful application of approaches, technology, models, techniques, instruments, and other tools that have proven to be effective in the use of water, land, and energy resources and in the protection of environment in Central Asia.

Best practices were selected based on their proven effectiveness in addressing current issues, sustainability, social significance and usefulness, scale of implementation and replication potential. The interactive map is scaled for 5 Central Asian countries: Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The map gives access to four spheres of practices: water resources, land resources, energy resources, and the environment. Each sphere comprises its own set of tools. The user may modify and update existing data and input new data.

The interactive map was developed by SIC ICWC under Project "Promoting dialogue for conflict prevention related to water nexus in Central Asia (CAWECOOP)" implemented by CAREC and financed by European Union.

The map is available at
http://riverbp.net/innovation/map-best-practices/en/base/index