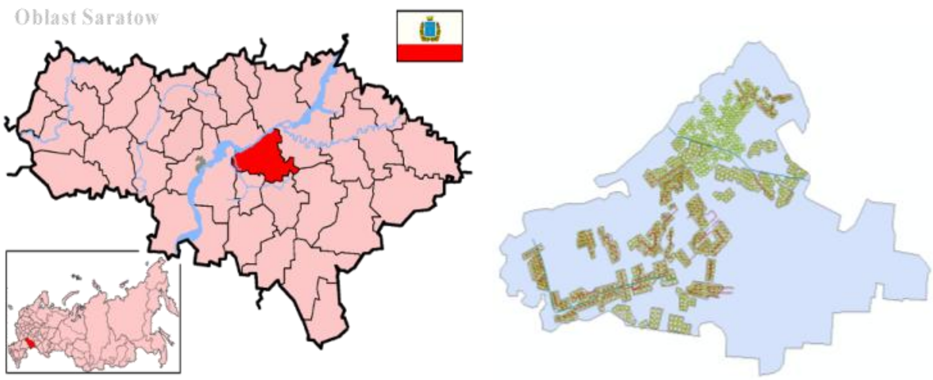
Novy study site, Russia

Highlights of work carried out in the DESIRE project
Based on work at Moscow State University, Russia

The study site

In the 1990s, the area of the irrigated lands in the Saratov region was cut almost by half. On the remained fields irrigating rates have been reduced, which has led to changes in the water balance. Now, 3 % of the irrigated lands suffer from salinity, plus salinity on some lands where the irrigation was stopped. It is important to determine which soils can be farmed sustainably, using a range of techniques to improve soil properties and recharge of groundwater.

The study site is situated in centre latitude of 51°15’ N and longitude of 46°25’ E. The predominant original and current land use type is cropland, specifically annual and perennial (non-woody) cropping. Land degradation caused mainly by ground water table rise and secondary salinization changes soil organic matter transformation, leads to its compaction, damage in structure, worsens hydraulic conductivity, water retention capacity and other soil parameters. In our opinion the major land use problems related to soil, water and vegetation in the area are high groundwater level, hence salinisation of soils and worsening of soil structure. From the land users’ point of view they are high groundwater level, not uniform pattern of soil fertility and extensive weed growth. Thus, the main degradation type is chemical soil deterioration, i.e. salinization: a net increase of the salt content of the top soil leading to a productivity decline. We determined the following main causes of land degradation: a) direct – disturbance of the water cycle, over abstraction of water (irrigation) and crop management; b) indirect – governance/institutional, as well as inputs and infrastructure (roads, markets, distribution of water points).



Novy Study site (51°82’ N, 47°03’ E) is located at Marksovsky District (29·103km2) of Saratov Region (Oblast) of Russian Federation. This region is situated in the southeast of the Eastern European plain named “Great Russian Plain” in the Lower part of Volga River, called Nighnee Povolzhie. (an area surrounding Volga downstream).

Since 1990's a new management concept for sustainable utilization of land and water resources for agricultural purposes was introduced these main idea to disintegrate experimental field in some management spaces with no similar properties. Nowadays this concept is known as precision agriculture or site-specific management by contradiction to conventional practices tending to treat a field as a single unit and manage it to optimize the average production as a whole.

From this time this concept starts to receive a great interest among researchers to develop new technologies breaking the field into several sub-units and treating them independently, thereof, the production of each unit can be optimized, rather than treating the entire field as an average (Maohua, 2001). Up to now, the main efforts and applications have been focused on site-specific crop management and has being tested for fertilizers and chemical applications through variable-rate technology. At the same time water need varies spatially in many fields because of saturated/unsaturated soil hydraulic properties spatial variability closely related to spatial heterogeneity of soil cover, landscape parameters and spatial variability of depth to ground water. Spots of different soil types inside of irrigated agricultural field may have different textures, water holding capacities and infiltration and drainage rates, therefore, the need for irrigation may differ between different zones of a particular field.

Previous generation of irrigation systems have been developed in the base of concept average parameterization of irrigated field and designed to apply the same amount of water through the hole field, without taking soil spatial variability into consideration, therefore, some areas may receive too much water and others not enough within one field. Excessive water application could contribute to surface water runoff and development of small ponds at the surface of irrigated field. From this ponds surface water is reaching deep soil and ground layers as well as ground waters by gravitary pore spaces and/or leaching of nutrients and chemicals to groundwater. Inefficient water application causes reductions in yield quantity and quality, inefficient use of fertilizers and other inputs, and lower overall water use efficiency. The use of precision farming for irrigation water management/scheduling, known as precision irrigation, in order to apply water in the right place with the right amount at the right time, is still in the development stages and requires a lot of experimental works to determine its feasibility and applicability. It is believed that, improving irrigation system performance to applied water uniformly over the field had received, and still, a great attention in both hands, research and technology or industry, and reached a stage, in which, any further improvements will not significantly increase in profitability. It is important now to shift toward and concentrate on maximization of the net profit from this water through applying it in the appropriate place and quantity.

It is possible to take the advantages of some existing technologies to be adapted for precision irrigation, such as speed-control systems, which are still used for constant speed along the whole field, although it can be used for different speeds. Other option is to take advantage of pulse concept to control single sprinkler (Frassie et al., 1995), single span or small segments along each span (Omary et al., 1997; Camp et al., 1998), through solenoid valves, which are known in irrigation market, but this needs software to control its operation. Therefore, the next generation in irrigation scheduling should be re-defined to have the ability to apply the right amount of water directly where it is needed, therefore, saving water through preventing excessive runoff/leaching is expected.

During 4th project year activities for Novy Study Site were realized according to the specific Site Implementation Plan that was developed. The presented below project activities have to contribute to the reducing of the use of scarce and high price water resources by the means of right spatial distribution of applied water within irrigated fields that stop losses of applied water by seepage into deep soil/ground layers and ground waters provoking their razing and secondary soil salinization.

Nowadays, this region is characterized by steady tendencies of a climate change aside aridification and formations of shortage of local water resources. Agricultural activities under irrigation are influenced by degradation of land and water resources as well and high final cost of agricultural production due to high water dozes using for irrigation, high price for water pumping & transportation and quite low average productivity.

Major land degradation problems in the geographical region called Saratovskoe Zavolghie going along left bank at the middle part of Volga River (Russia) are caused by

- ✓ long time large scale irrigation projects based started since the middle of 1960th based on sprinkler irrigation technology of annual and multiyear forage crops;
- ✓ short time small scale irrigation activities started since middle of 1990th based on furrow irrigation technology of vegetables.

Major soil degradation problems :

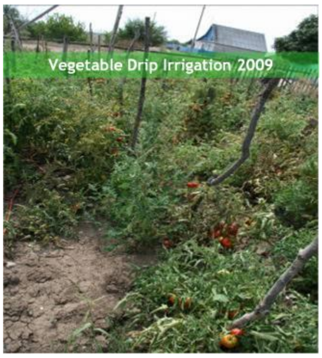
1) Ground Water Logging
2) Secondary Soil salinization
3) Not uniform irrigated soil properties

Two SLM technologies at local and regional scales are proposed :

1. Drip Irrigation of vegetables instead of Furrow Irrigation
2. Precision Irrigation of forage instead of “Overall” Irrigation

A Geo Data Base of Ground Water, Soil Salinity and Plant Cover Monitoring was made.

Widespread sprinkler irrigation has led to soil salinisation.



Furrow Irrigation of vegetables provides:

1) unproductive use of irrigating water;

2) sharp increasing of subsurface/ground waters;

3) over watering of root layer of soil;

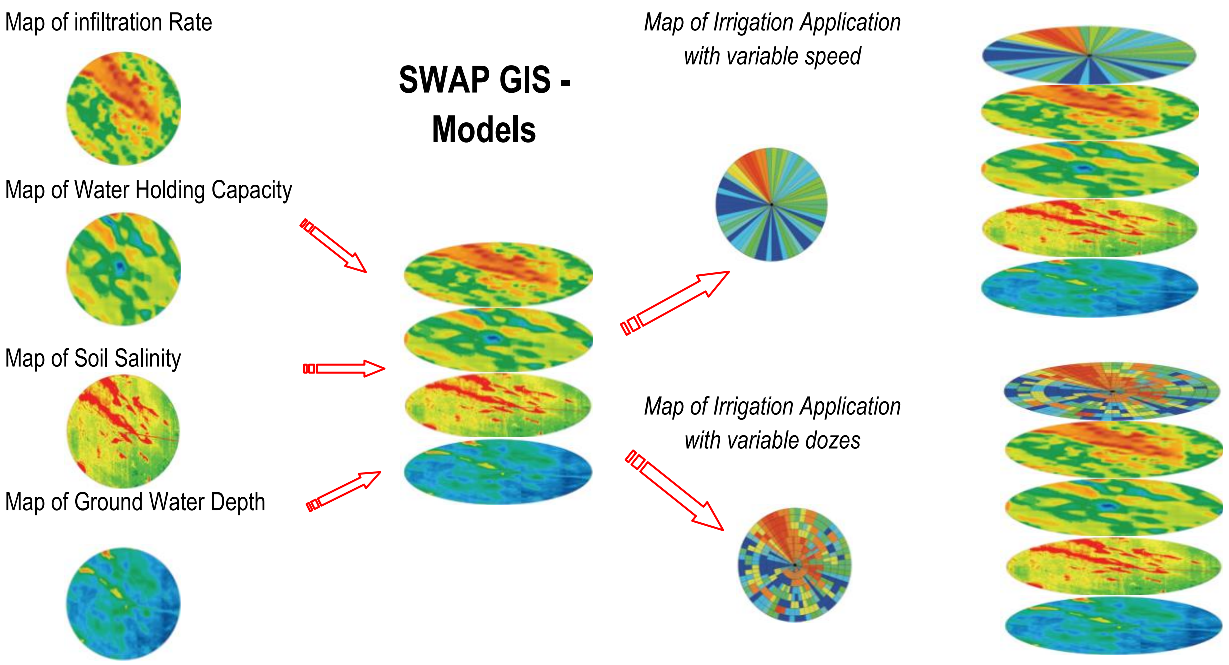
4) pollution of the subsoil/ground waters by chemicals;

5) occurrence of water erosion and leaching of nutrients.

During 3rd and 4th of DESIRE project years MSUEE team started a research activities aimed :

- ✓ review the state of precision irrigation for land areas with chernozem (chestnut) soil cover exhibiting alkali zones with low infiltration rates;
- ✓ provide necessary background soil/land information helping to delineate spatially heterogeneous irrigated field into quasi-homogeneous zones;
- ✓ develop a strategy for application of precision irrigation farming.

A general framework for developing a irrigation application map is presented at fig.1.



Framework to develop maps of irrigation applications of variable rate irrigation technologies

Location of the central point as well as perimeter of irrigated field (using a length irrigation machine span) shown at satellite image The next information needed to delineation of field spatial variability in the border of pivot sprinkler system is originated from the soil maps of irrigated fields. This information is not sufficient to be used for precision irrigation, since these maps provide information about spatial variability at quite large scale by comparison with dimension of quasi-homogeneous polygons.

The next step was to obtain *in-field* information (small scale) with different type of soil sampling techniques for following laboratory analyses and/or special in-field soil properties analyzers like vacuum-infiltrometer dealing with measurements of infiltration rate by capillarity (without surface water dept developing) , soil penetrometers, and/or non-destructive real-time sensors like GPR and/or EM38, providing surrogated properties, such as EC. This was followed by soil sampling, based on the maps produced from this sensor, and correlate the surrogate property with the property in question (EC vs. AWC). Map for the management zones within the field (application map) for the field activity, here irrigation, showing the different quantities (depths) and their location within the field is established. Then a decision must be taken concerning the technologies that must be integrated with the present field machinery or need to be introduced, here, variable-rate technologies. Evaluations for the parameters of this technology, here travel speed and discharge rate, should be done.

Soil Variability Delineation

Soil electrical conductivity (EC) maps were determined without physical contact between the sensors and the soil by use of commercially available dual coil Electromagnetic Induction (EMI) systems (Rhoades, et al., 1989; Hendrickx et al., 1992; Sudduth et al., 1999; Dalgaard et al., 2001; Domsch and Giebel, 2001; Sudduth et al., 2001). An EMI meter, EM38, developed by *Geonics Limited, Mississauga, Ontario, Canada*, provides fast non-destructive measurements of apparent soil EC. Principle of measurement is described in the above literatures. For soil reconnaissance to quantify EC (mS/m), EM38 sensor, after calibration and in the vertical operation mode, mounted on a PVC-sledge together with a DGPS unit was traveled across the field along the tramlines 5 m apart. The DGPS data were integrated with EM38 data to provide the co-ordinates of each measurement point. Values for EC and position with sub-meter accuracy for each individual measurement was merged and stored at a rate of 1 sec-1. The reading were logged to a data logger and interpolated using some models using ArcGIS to produce EMI-soil conductivity map.

The presented above procedure of irrigated field delineation was carried out in 3-experimental fields. The resulted maps are showing zones with different soil EC-ranges, and in each zone sample positions were selected depending on the co-ordinates using DGPS. The soil auger-samples to a depth 90 cm from those zones were collected to determine the water holding capacity in laboratory. The same sampling points were subjected to in-situ description for texture using feeling method.

During a field monitoring campaign following variables were measured at both study sites according to shown in the Table 1 calendar.

Table 1. Variable measured during field monitoring of SLM technologs at both study sites

Variable	*2007*			*2008*			*2009*			*2010*		
	Vi	VII	VIII	Vi	VII	VII	VIII	VII	VIII	Vi	VII	VIII
Soil Moisture												
Electrical Conductivity												
Air Temperature												
Germination Rate												
Growth quality												
Soil chemical analysis												

ANALYSIS AND RESULTS

Water for agricultural and domestic purposes at this region is pumped from Volga River and mounted to uphill areas by networks of pumping stations and open transportation canals in some cases going till hundred kilometers into desert & semi-desert areas. In irrigated areas located near Volga River (maximum about at distance of 20 km) water is pumped from these canals by lateral pumping stations distributing it to pivot sprinkler machines. These machines are carrying out water application at the irrigated field areas of around 40-50ha. At the same time water from open transportation canals is also delivered for small farms cultivating vegetables at field with inclined soil surface providing driving force to carry water flow through out line of lengthwise furrows with simultaneous lateral soil moistening of seedbed as well as high infiltration into soil/ground profile from furrow beds.

In the frame of FP6 DESIRE 037046 (2007-2011) project aiming to assess main land degradation driving processes in Saratovskoe Zavolghie region as well as introduce an appropriate innovation technologies after field experimental results it was shown that an extensive irrigation at this region based on sprinkler technology with the rate not adjusted to soil infiltration/retention parameters has provoked a considerable ground water table rising and by consequences secondary soil salinization.

Overall efficiency of irrigated agricultural cropping systems depend on the water needs that vary not just in the time space, but also in within space of irrigated fields. From 1-D (vertical) modeling point of view time variability of crop water needs in one simulated spatial area presented like point-area depend of appropriated parameters at this point-area linking water and energy flows processes called Soil-Water-Atmosphere-Plant (SWAP) continuum. From this concept time variability of crops depends of crop type, crop vegetation state, soil surface aspect, weather conditions, texture & structure of soil profile, amount of available water in the soil root zone as well as amount of nutrient. Spatial heterogeneity (variability) of crop needs within field area of spatial 1-D modeled points depends of the variability of the same parameters but in case of irrigated water application this variability is controlled by spatial variability of field parameters like topography, texture & structure, water holding capacity, as well as soil infiltration and drainage rates. In many case this spatial point variability of key SWAP parameters may be regionalized (homogenized) by assembling of spatial point into quasi-homogeneous spatial zones in the base of some spatial relationships between neighboring point-spaces.

Due to this spatial variability at the same time period the needs for irrigation differ between different spatial zones of a particular fields. While moving irrigation systems apply water at constant rates, some areas of the field may receive too much water and others not enough. Sophisticated technology of water application based on precision irrigation agriculture concept should avoid such spatial disproportions on water receiving by soil root depths by the knowledge of the right spatial places and the right spatial amounts as well as by the means of spatial water application control.

After results of filed experiments it was shown that ground water rising at irrigated areas is originated by considerable irrigated dozes used for irrigation water application and high sprinkling intensities as well as irrigated water losses presumably by preferential flow process descending it into deep soil & ground layers and reaching ground waters. In they turn these losses of applied water applied have been provoked by commonly used technology called "**uniform rate irrigation"** that are not appropriated to complex soil cover structure of irrigated fields due to spatial non-uniformity of key parameters like mezo-topography, water holding capacity and infiltration rate. During water application by such type of technology where the soil intake rate is exceeded, thus causing water run-off with water ponding in micro- and mezo-depressions with following water seepage by preferential flow and as consequence - groundwater rising, secondary salinization/alkalinization leading in their turn to degradation of land & water and environment. At the same time inside of irrigated fields there is development of areas with root zone over or under moistened exhibiting water stress of crop plants and finally provoking low productivity and lost of yield.

INVOLVEMENT OF STAKEHOLDERS

Contributions of an information about field activities with two SLM technologies (drip irrigation for small scale areas and variable rate irrigation for large area) were presented and discussed during official and not official meetings in Russia with different groups of stakeholders from central, through out regional till local levels.

After overall opinion of different stakeholders regarding drip irrigation technology using instead of furrow irrigation is very positive with expectance of high water efficiency under conditions that water price politics should stop no efficient water use.

After overall opinion of different stakeholders regarding non uniform spatial water application technology (variable rate irrigation)) instead of spatially uniform water application technology is very positive with expectance of high water efficiency using for irrigation as well as with raising overall yield in case if water price politics should stop no efficient water use for sprinkler irrigation.
Both SLM technologies under field testing in the frame of DESIRE project were included in Concept of Land Reclamation at Russian Federation for the period till 2020.

DISCUSSION AND CONCLUSIONS

As a practical consequence of this study a new concept of irrigation technology called "**non-uniform irrigation**" is proposed. After this concept this technology should provide site-specific irrigation management by the application of different volumes and/or rates of irrigation water to different areas of a field matching spatial non-uniformity of soil cover structure, water holding capacity of root zone, water infiltration/drainage rates, ground water depths as well as soil salinity/alkalinity.

Experimental results of soil moisture monitoring at field irrigated with the use of "**uniform rate irrigation"** as well as results of computing simulation with scenario of "**non uniform rate irrigation"** with their spatio-temporal interpretation are presented in the contribution. Main options of supportive mapping technology aiming to delineate irrigated field into quasi-uniform areas are discussed. The future challenge is to build a rich database in order to formulate a complete decision support system for precision farming, including all field activities i.e. irrigation, fertilisation, tillage, plant protection and weed control.

The use of precision agriculture for irrigation water management is still in the development stage and requires a lot of investigation and experimental work to determine its feasibility and applicability. The availability of some low-cost data gathering methods, positioning systems and the development in computer programming will help in regulating the depth of water within a field. So the next generation in irrigation scheduling is not just when-how much but when, where and how much to irrigate. A precision irrigation system expected to have the ability to apply the right amount of water directly where it is needed, therefore is saving water through preventing excessive water runoff and leaching. So the suitable technology to control varying amounts of water in direction of traveling and crosswise has to be developed.

Final Conclusions

Precision Irrigation is promising SLM technology for large field/area. Its implementation needs a synergy of :

1) Robotized irrigation engine able spatially differentiate the application of water;

2) Geo-database of land-soil-groundwater properties;

3) Spatially distributed monitoring of soil moisture and plant water stress.

Leading scientists:

Prof. Anatole Zeiliguer
azeiliguer@mail.ru

➜ Contact address: ALTERRA, Soil Science Centre/ Coen Ritsema, P.O. Box 47, 6700 AA Wageningen, The Netherlands
Phone: +31 317 48 65 17
Fax: +31 317 41 90 00

➜ This project has been funded by the European Commission DG Research-Environment Programme
Unit of Management of Natural Resources
Head of Unit *Pierre Mathy*, Project officer *Maria Yeroyanni*

During the period January 2007- January 2012, this work was carried out by:
Prof. Anatole Zeiliguer
Olga Ermolaeva

See: http://www.desire-his.eu/en/novy-russia for full details of DESIRE research