# Abstracts of the

# 13th ICID International Drainage Workshop

## Ahwaz, Iran, 4 - 7 March 2017

## Drainage and Environmental Sustainability

International Commission on Irrigation and Drainage
Iranian National Committee on Irrigation and Drainage


## Abstracts of Papers

# 13th ICID International Drainage Workshop

**Ahwaz, Iran, 4-7 March 2017**

# Drainage and Environmental Sustainability

**International Commission on Irrigation and Drainage (ICID)**
**Iranian National Committee on Irrigation and Drainage (IRNCID)**

**Organized by:**

International Commission on Irrigation and Drainage

Iranian National Committee on Irrigation & Drainage

Khuzestan Regional Committee on Irrigation & Drainage

Khuzestan Water and Power Authority

Iran water Resources Management Company

Islamic Republic of Iran Ministry of Energy

**Hosted by:**

Khuzestan Water and Power Authority

**The International Commission on Irrigation and Drainage (ICID), established in 1950 is the leading scientific, technical and not-for-profit Non-Governmental Organization (NGO). ICID, through its network of professionals spread across more than a hundred countries, has facilitated sharing of experiences and transfer of water management technology for over half-a-century. ICID supports capacity development, stimulates research and innovation and strives to promote policies and programs to enhance sustainable development of irrigated agriculture through a comprehensive water management framework.**

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**13th ICID International Drainage Workshop**
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**Rahim Meydani**
**Deputy Minister of Energy for Water and Wastewater Affairs and Chairman of IRNCID**

Dear Participants,

Having the honor to welcome all respectful delegates and accompanying persons from various countries around the world, I am very pleased to inform you that the 13th International Drainage Workshop (13th IDW) is currently being held in the beautiful city of Ahwaz, in Khuzestan Province as one of the main agricultural and economic hubs of Iran.

Indeed the event is a valuable opportunity for drainage scholars and experts from all over the world to bring together the technologies, experiences and the latest findings of drainage to be further investigated with the aim of coming up with new approaches and solutions towards better and efficient agriculture with due consideration to environmental aspects of drainage and promotion of drainage management for environmental sustainability

As we are all aware, the International Commission on Irrigation and Drainage (ICID) once every two years holds international drainage conferences in one of the member countries. The first International Drainage Conference (IDW) was held in Wageningen, The Netherlands in 1978, and the last one was held in St. Petersburg, Russia, June 2014. Now we are in the stage of hosting the 13th International Drainage Workshop in Ahvaz, with its pleasant weather at this time of the year. This event is organized by IRNCID and hosted by Khuzestan Water and Power Authority (KWPA).

Worth noting that, Khuzestan province is the birthplace of drainage in Iran. About 60 percent of drained area of the country is in Khuzestan. In addition, there are many ancient unique hydraulic structures in the region such as Chogha Zanbil Ziggurat, an ancient complex built around 1250 B.C. accompanied with water treatment facilities. I hope the participants of the workshop will find the opportunity to visit modern drainage networks and enjoy the ancient hydraulic structures dating back to over 3000 years.

I would encourage your participation, appreciate your kind cooperation and look forward to reviewing the fruitful results of this fabulous event. Last but not least, I intend to submit the outcomes of this international event in the fourth coming official meetings I have with the Commission on Agriculture, Water and Environment of the Islamic Republic of Iran Parliament.

Wishing you a very pleasant and memorable stay.

**M. R. Shamsaei**
**Chairman and Managing Director**
**Khuzestan Water and Power Authority**

On behalf of the Khuzestan Water and Power Authority (KWPA), I have the pleasure to welcome all researchers, scholars and experts to participate in the 13th International Drainage Workshop (13IDW) which will be held in Ahwaz, Iran. Unique capacities in water, soil and climatic conditions has made Khuzestan plain an attractive place to different ethnic groups in years. Double cropping is possible here in Khuzestan province having two summers and mild winters, a unique characteristic throughout the country. Among other characteristics are salt affected heavy soils requiring drainage facilities. The Shavoor open drainage system was constructed back in 1956 followed by the development of sugarcane plantation covering 12,000 hectares of Haft Tappeh as the first subsurface drainage system in the 1970s. These developments shows the historic significant of the development of drainage systems in the south western Iran.

I am quite sure that being familiar with the technical tours in the province, along with the most interesting and tourist worthy cultural tours brings you unforgettable moments of your stay in Iran. During the workshop, you may enjoy visiting historical unique hydraulic structures in Khuzestan including Choqazanbil, the only remnant of an ancient city that was constructed approximately in 1300 BC. You should not miss the chance to visit Shushtar historical hydraulic system, a masterpiece of creative genius be traced back to Darius the Great in the 5th century B.C. I hope that the workshop provides you with the chance to be familiar with KWPA's years of experience in irrigation and drainage network developments, adapting new design criteria, followed by finding the best practice managements in favor of the environment. We will do our best to take all the opportunities to provide all participants a memorable stay and a successful workshop.

**Dr. Saeed Nairizi**
**President, ICID**

Water and food security will continue to remain as the main global concerns for the years to come. The growing demand on food requires 60% increase in world food production by the year 2050 where this target would be achieved if such enhancement in developing countries doubles over the next 30 years. Irrigated agriculture is expected to play the major role in this ambitious goal and global endeavor. Higher yields and expansion of irrigated area supported by innovation in technology and irrigation revitalization appear to be the main potential options, particularly for developing countries, to meet their food security challenges.

However, irrigation development inhere adverse environmental consequences which should be managed appropriately. To minimize negative impacts of irrigation practices such as water logging and salinity and hence to maintain or improve the land productivity, drainage of agricultural land is essential and considered as a part of integrated land and water resources management approaches.

ICID through its Working Group on Sustainable Drainage and assisted by the Iranian National Committee on Irrigation and Drainage (IRNCID) and hosted by Khuzestan Water and Power Authority (KWPA) is organizing the 13th International Drainage Workshop, IDW 13, in Ahwaz, Iran 4-7 March 2017. Under the theme of "Drainage and Environmental Sustainability" the Workshop will focus on (i) Measures to lower volume of drainage water; (ii) Measures to improve drainage water quality; (iii) Adoption of new

design criteria in favour of the environment; and (iv) Application of alternative drainage methods.

I am delighted to see the enthusiasm of the host to expect a large number of participants consisting of decision makers and officials, academician, scientists, and drainage system managers from different countries who are interested in sharing their experiences and being engaged in various technical deliberations.

The workshop program also consists of several side events and technical tours which definitely attract the participants with a variety of tastes. For instance two round tables on "Alternative Drainage Methods" and "Water Reuse" along with the second management board of ICID-International Research Program on Irrigation and Drainage (ICID-IRPID) - Iran Regional Node (IRPID- RN- I) and several side lectures in different universities such as "Role of Drainage in a Historical Perspective and Challenges for the Future" and many more are amongst the programs of this international event.

A fabulous exhibition is also being organized during these days with the attendance of around 25 companies demonstrating their products, activities and achievements in the field on Drainage.

I am quite confident that we will all benefit from the innovative methods and products presented in the exhibition.

I look forward to meeting you all in person during this important event.

## International Drainage Workshop

The International Commission on Irrigation and Drainage has held technical and professional conventions on various topics related to irrigation and drainage during its active years.
The professional workshops includes, the International Drainage Workshop held in 1978, and ever since, it has taken place in one of the member countries. The upcoming convention is the 13th International Drainage Workshop, which will be held during the 4-7 March 2017, Ahwaz, Iran.

### Previous Workshops

| | | |
|---|---|---|
| 12th IDW | St. Petersburg, Russia | June 2014 23-26 |
| 11th IDW | Cairo, Egypt | September 2012 23-27 |
| 10th IDW | Helsinki, Finland/ Tallinn, Estonia | July 2008 6-11 |
| 9th IDW | Utrecht, The Netherlands | September 2003 10-13 |
| 8th IDW | New Delhi, India | January - 4 February 2000 31 |
| 7th IDW | Penang, Malaysia | November 1997 21 – 17 |
| 6th IDW | Ljubljana, Slovenia | April 1996 23 – 21 |
| 5th IDW | Lahore, Pakistan | February 1992 15 – 8 |
| 4th IDW | Cairo, Egypt | February 1990 24 – 23 |
| 3rd IDW | Columbus, Ohio, USA | December 1987 |
| 2nd IDW | Washington, USA | December 1982 12 – 5 |
| 1st IDW | Wageningen, Netherlands | May 1978 17 – 16 |

# 13th ICID INTERNATIONAL DRAINAGE WORKSHOP

## THEME: Drainage and Environmental Sustainability

The theme of the workshop will be drainage from the viewpoint of environment. Obviously, if drainage is not properly designed, implemented and managed it could become a factor for environmental damage. Recently damaging impacts of drainage to pollution of water resources are very much considered in the world.

In Iran, in most cases, the rivers supply irrigation water and at the same time receive the drainage water. This has caused a lot of environmental, health and social problems in downstream. Karun River water salinity, for example, increases from 1 dS/m in upstream to 4 dS/m in the downstream area. This is because nearly 40 percent of water diverted from the river for irrigation, flows back into the same river through the drains. This indicates that not only the drainage water is of poor quality; but also its volume is above normal. There are similar problems in some other countries, especially in arid and semi-arid regions.

In addition, due to the higher salinity of ground water in deeper soils, if drains are installed deeper, more saline drainage water flows from the deeper strata. Since there is no need to drain soils much deeper than the root zone, shallower drains might be more suitable. In recent years few arid and semi- arid countries (like Iran) started to reduce their drain depths from about 2.0 to nearly 1.5 meters in order to prevent over drainage as well as over pollution. However, it seems more research will be required to reach to new standards and design criteria leading to optimize technical, economic and environmental issues.

Alternative methods of drainage, such as bio drainage, dry drainage and controlled drainage, in some cases can replace conventional methods. However, it seems that more local researches are required. After carrying out researches, we would expect a reduction in drainage environmental problems by practicing alternative methods. In Iran, for instance, we found by chance that in Gamsar, in the margin of Dasht-e-Kavir, the main desert of the country, farmers traditionally practice dry drainage. They are facing shallow water table and poor quality water. Their lands are more than what they could be irrigated with their available water. They have divided their land in parallel strips and cultivate in every other one. The remaining uncultivated strips are the sinks of salts and drainage water in which the shallow ground water evaporates and the salt concentrates. In this way, they drain their land and get rid of severe soil salinity in cultivated strips without using any artificial drainage system. This method could be assumed rather environmentally friendly and to some extent sustainable since it has been practiced for a long time.

Hence, the workshop considers following topics:

- Topic 1: Measures to improve drainage water quality;
- Topic 2: Measures to lower volume of drainage water.
- Topic 3: Adaption of new design criteria in favor of the environment;
- Topic 4: Application of alternative drainage methods.

# Keynotes

# Value Engineering for unbiased design in Irrigation and drainage projects

**(Case Study: Ramhormoz irrigation and drainage project in Iran)**

Kamran Emami [1], Mojtaba Akram [2]
Saeed Pourshahidi [2], Jafar Al-e-Tayeb [2]

**ABSTRACT**

All designs are biased due to the expertise, experiences and orientations of the designers and clients. Value engineering is a proven technique for improving the value of projects, products and services. The value engineering methodology is based on the synergy and creativity of an independent team. The independence and outside perspective of the team would reduce and bias in the design and consequently would result in saving and enhanced benefits for the projects.

Value Engineering Change Proposals (VECP) are post-award value engineering proposals made by construction contractors during the course of construction under a value engineering clause in the contract. These proposals may improve the project's performance, value and/or quality, lower construction costs, or shorten the delivery time, while considering their impacts on the project's overall life-cycle cost and other applicable factors. The Ramhormoz project is medium size 5500 hectares on-farm project located in Khuzestan province in southwest of Iran. Value Engineering Change proposal submitted by the contractor in 2014 included 2 proposals on changing the orientation and geometry of drainage laterals. The approved savings by the client was estimated to be about 3.2 million USD (16% of the total cost). The proposals would also improve the schedule of the project. This paper describes the procedure of the value engineering study and compares the benefits of the proposals to the base case specifications.

[1] Chair,Task force on value engineering for saving in irrigation and flood projects
[2] KuritKara Consulting Engineers

# TRANSPORT OF VIRUSES AND COLLOIDS IN PARTIALLY-SATURATED SOIL AND GROUNDWATER

Seyed Majid Hassanizadeh [1,*], Gholamreza Sadeghi [2]
Zhang Qiulan [3], Jack Schijven [4]

**ABSTRACT**

Surface water is often used for the recharge of aquifers used in drinking-water production. Surface water is often contaminated with pathogenic micro-organisms and viruses. These pathogens have to be removed to produce safe drinking water. One effective way is the passage of surface water through soil, as is the case in bank filtration, dune recharge, and deep-well injection. Dune recharge is widely applied in The Netherlands, where surface water, after some pretreatment, is fed into canals in protected dune sands. Then, water is abstracted after 50 to 60m of passage through the soil. To assure production of safe drinking water from surface water, adequate travel times and travel distances are needed. In this regard, it is important to determine various factors that affect the rate of removal of pathogenic viruses during soil passage. These factors include hydraulic conditions (such as flow velocity and saturation) and geochemical conditions (pH, ionic strength, concentration of calcium, etc.).

In some parts of the world, use of grey water (e.g. kitchen/shower wastewater or treated wastewater) for agricultural purpose is practiced or is being considered. In such cases, it is essential to determine whether the infiltrating

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[3] Assistant Professor, Beijing University of Gesciences, China
[4] Professor of Quantitative Water Safety, National Institute of Public Health and Environment, The Netherlands

water will be droid pathogenic micro-organisms when it reaches groundwater. In this lecture, we present results of a large number of laboratory and field experiments for the study of movement of bacteriophages (these are harmless viruses that are used as surrogates for pathogenic viruses) through soil and colloids through a micro-model (an artificial porous medium). Experiments are carried out under a variety of conditions: a range of pH values, a range of ionic strength values, different Ca concentrations, and different water saturations; all under steady-state flow conditions. This data are used to derive (empirical) relationships between removal rate coefficients and geochemical conditions as well as soil moisture content. In the case of unsaturated flow, the role of air-water interfaces in the removal of viruses has been also investigated. We have also performed experiments under transient flow conditions both in sand columns and in micro-models, where water content has been changed significantly. Our experiments as well as other researchers' results have shown that both drainage and imbibition fronts cause a remobilization of adsorbed viruses. We discuss the mechanisms behind this remobilization and provide evidence from pore-scale visualization experiments. Such a remobilization was also observed when the calcium concentration was changed significantly.

# DRAINAGE MANAGEMENT FOR CROP PRODUCTION AND WATER QUALITY BENEFITS

Ali Madani [1]

**ABSTRACT**

Nearly all agricultural soils require drainage. Artificial or improved drainage is essential to produce crops on most agricultural soils. Subsurface (tile) drainage systems are designed and installed to remove excess water from the soil profile to improve traffic ability and to facilitate timely seedbed preparation, planting, and harvesting. In dry regions, where irrigation is practiced, drainage systems may be required to maintain a suitable salinity level in the soil profile.

While some of the most productive agricultural soils are artificially drained, artificial drainage is blamed as a major contributor to water pollution. Results of numerous studies throughout the world have shown concentrations of agri-chemicals, pathogens, and other detrimental pollutants in subsurface water as well as groundwater.

Research has shown that management strategies can be used to reduce pollutant loads from agricultural drained lands. These strategies range from agricultural drainage water management to cultural and structural measures. A number of approaches have been identified as cultural and structural practices. These practices include routing of drainage water through constructed wetlands, precision agriculture, and nutrient management. This presentation will focus on these strategies as well as the use of simulation modeling on a watershed scale.



* Nova Scotia Institute of Agrologists, Nova Scotia, NS, Canada

# IMPROVING IRRIGATION AND DRAINAGE EFFICIENCY USING EDDY COVARIANCE, SCINTILLOMETERY AND COSMOS TECHNOLOGIES

Ragab Ragab [1]

**ABSTRACT**

In the context of increased pressure on water resources for food production, where globally some regions are already in water crisis, it is necessary to maximize yield for a given water resource. For irrigated crops, this means not only more efficient application of water, but also an improved understanding of crop water requirement.

Modern technologies to measure actual evapotranspiration (ETa) such as Large Aperture Scintillometer (LAS) and Eddy Covariance (EC) instruments can offer alternatives to the widely used potential evaporation equations such as those of FAO. Potential Evapotranspiration, ETp based on equations represent the atmospheric demand for water rather than the actual crop demand for water. Actual evaporation Eta represents the crop water requirement and is expected to be lower than the potential evapotranspiration, ETp.

The very recent field experiment results showed significant differences between actual evaporation values measured by the Eddy Covariance and Scintillometer when compared with the worldwide used potential reference evaporation, ETo, calculated from meteorological data using Penman-Monteith equation and the crop potential evaporation, ETc, which is based on the ETo and the crop coefficient, Kc. The ETc and ETo showed higher values than those of ETa obtained by Eddy and Scintillometer. On average the actual evaporation measured by Eddy Covariance and Scintillometers represented nearly 50% of the ETo. These are quite significant differences.

These results indicated that there is a potential for water saving in irrigation, should the crop water requirement be based on actual measured evapotranspiration rather than on the calculation based on the widely used Penman–Monteith equation and possibly other methods of calculating potential evaporation, not

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the actual evaporation. This proves that for realistic crop water requirement estimation, one should consider methods based on crop demand rather than the atmospheric demand for water.

The exact percentage of water saving by using these modern technologies, will differ between seasons and crops but will always be actual irrigation water requirement. Another benefit is that these modern technologies of measuring the actual evaporation do not need the crop coefficient Kc, which for many irrigation practitioners is difficult to obtain.

The field results showed that soil moisture obtained by COSMOS was comparable with those obtained for the top 50-60 cm soil layer soil moisture measured by sensors, soil cores and profile probes and simulated by the SALTMED model. This indicates that there is a possibility that COSMOS probe's effective depth could be within the top 50-60 cm of the irrigated lands particularly during the summer crop seasons. In such case, knowing that almost 80% of the crop root system is accommodated within the top 50-60 cm, the COSMOS measurement could be useful for monitoring the soil water status and subsequently soil moisture deficit in the root zone. The Cosmos results could be made operational for irrigation managers to determine when and how much to irrigate to avoid harmful water stress. The COSMOS technology is one step in the right direction as it provides continuous, integrated, area based values and solves the problem of spatial variability often found in point measurements in relation to the soil spatial heterogeneity. This method could also be used to determine the soil moisture deficit, hence determine when and how much to irrigate.

The above modern technologies, Eddy Covariance, Scintillometer and COSMOS proved their suitability for use in agricultural water management. They can improve water use efficiency, save water, reduce drainage volume, and reduce water logging and salinity.

# AGRICULTURAL WATER MANAGEMENT AND FOOD SECURITY IN A SUSTAINABLE ENVIRONMENT

Bart Schultz [*]

**ABSTRACT**

The Worlds' population is expected to grow from 7.4 billion at present to 10.0 billion by 2055. Combined with the expected rise of living standards, improvement in life expectancy, urbanisation and growing demands for animal feed and energy from crops this requires, among others, a substantial increase in cereal production to ensure food security. Overall, global cereal production meets the current demand and the global cereal stock is stable. Achieving the required increase in cereal production in a sustainable way seems to be possible. In the framework of rural reconstruction irrigation and drainage will have to play a major role in achieving the required increase in cereal production, while most of the increase will have to be realised at already cultivated land and land reclamation can only result in a relatively small contribution. This implies a focus on approaches and solutions that on the one hand will result in the required increase and on the other hand are environmentally sustainable. In light of this upgrading, modernisation and expansion options for irrigation and drainage schemes will be presented with special attention to the role of drainage. This will be done with due attention for the Sustainable Development Goals (SDG) and the draft Action Plan 2030 of the International Commission on Irrigation and Drainage (ICID).

[*] Professor em. in Land and Water Development, UNESCO-IHE, Chair Group Land and Water Development, Delft, the Netherlands, Former top advisor Rijkswaterstaat, Utrecht, the Netherlands, President Honoraire ICID

# BEYOND MODERN LAND DRAINAGE

Willem F. Vlotman [1]

**ABSTRACT**

Modern Land Drainage implies making drainage environmentally sustainable which includes enhanced water balance assessments at regional and field scale (incl. a detailed look at water movement on the root-zone), prevent excess water except for leaching salts, support ecological water requirements, and then if any access water remains design a drainage system. The less water is mobilised thorough our agricultural lands, the better the quality of water will remain. No matter how efficiently our crops are watered, sooner or later we need to have a well-functioning drainage system for complete in-field water management. Under natural conditions, i.e. in areas with rainfall surplus and no irrigation system, drainage is considered when causing waterlogging that restricts crop growth. Salinisation of the land, i.e. the accumulation of salts in the upper layers of the soil occurs naturally in coastal areas but can be a secondary effect of waterlogging. In all cases the absence of a sustained seasonal net downward water movement through the root-zone is generally the reason for salinisation. Beyond modern land drainage includes various approaches to assessment, prevention of waterlogging an salinity problems, considers the water-food-energy nexus approach and gives due attention to ecological considerations for more sustainable results. Theories of drainage design have been well developed and with powerful computing now available at the desktop at affordable prices, many solutions to a drainage issue can be considered that include controlling the amount of water drained, reuse and how best to control drainage water quality. Ready access to satellite imagery, new and enhanced existing computer models to simulate land inundation and the recent advance in the use of drones with cameras (quad copters and the like) provide an opportunity to enhance integrated water resource imbedded drainage design. Regardless of these technological advances nothing beats going out when it rains to assess what is really happening in the field. A holistic approach to drainage is describes that includes steps to successful stakeholder involvement from beginning to end, from farm to fork and from minister to manager.

[*] Irrigation and Drainage Consultant, Willflow Consulting, Canberra, Australia.

# 1

# Topic 1:
# Measures to Lower Volume of Drainage Water

# EFFECTS OF AGRICULTURAL DRAIN WATER CONSUMPTION ON THE GROWTH OF JUVENILE DATE PALM

Majid Alihouri [1,*], Abd Ali Naseri [2]

**ABSTRACT**

The efficient use of irrigation water is one of the important issues and programs of the agricultural sector in Iran. The purpose of this study is the exploring of the possibility of juvenile date palms irrigation utilizing agricultural drain water. This experiment was carried out using acomplete block design with three irrigation water salinities of 2.5, 8 and 12 dS m-1 in four replications. Saline water with 8 and 12 dS m-1 were obtained from a mix of agricultural drain water and water abstracted from the Karun River. The results show that the salinity of irrigation water had a significant effect on soil salinity, the number of leaves, leaf length, leaf width, number of leaflets and truck perimeter at 5% level of probability. The maximum and minimum of plant vegetative characteristics except for leaf chlorophyll and leaflet width were obtained from water with 2.5 dS m-1 and 12 dS m-1, respectively. There was a significant difference between the water with 2.5 dS m-1 and 8 dS m-1 in terms of leaf number, leaf width, number of leaflets and truck perimeter. Therefore, saline water (EC ≥8 dS m-1) cannot be used for irrigation of juvenile date palms.

**KEY WORDS:** Irrigation, Lysimeter, Saline water, Salt, Soil salinity.

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[2] Professor, Faculty of Irrigation and Drainage Department, Shahid Chamran University of Ahvaz.

# EFFECTS OF CLIMATE CHANGE ON SURFACE DRAINAGE (CASE STUDY: ILAM DAM WATERSHED)

Sepehr Dalilsafaee [1,*], Bahman Moshtaghi [2]
Mohammad Hossein Niksokhan [3]

**ABSTRACT**

Water is essential to human survival, and changes in its supply from overland flow can potentially have devastating implications, particularly in Iran, where much of the population relies on local rivers for water. Future climate change may pose one of the greatest threats to poverty eradication plans in this country, and related changes in surface water supply will exacerbate this threat. Climate change will alter the duration, intensity, type and timing of precipitation. This can cause unprecedented droughts and floods. Whatsmore, it changes the volume, timing, and duration of the runoff, leading to many changes and developments in the field of water resources management. Early spring runoff in snow-fed rivers will lead to increased flooding. In addition to the primary impact of floods on lives, crops, livestock, and property, they bring the threat of epidemics in their aftermath. Increased surface drainage capacity may be required to prevent crop damage or loss or even the threatening of haman and animal lives. Runoff and overland flow ultimately effect land erosion and sediment transport to surface drains. Sediment itself is a major carrier of contaminants such as phosphorus, heavy metals, and the residue of pesticides and herbicides, which in themselves affect the

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[3] Associate Professor, Department of Environmental Engineering, Faculty of Environment, University of Tehran, Niksokhan@ut.ac.ir

health of receiving open water bodies.
Ilam dam basin which is 471.6 km2 is located in western Iran. The basin consists of three rivers originating from three sub-basins joining at the dam site. Rain-fed cultivation is a prevailing type of agriculture in the aforementioned basin (about 80% of the total area of agricultural lands in the basin). Therefore Agriculture in this region depends critically on weather conditions so that every change in weather conditions can greatly affect the cropping pattern.
In this study, a commercial hydrological model (SWAT) with A2 and B1 emission scenarios predicted usingHadCM3 General Circulation Models (GCMs) in a future period (2046-2065) were applied to determine the total runoff volume and peak rate. By applying various climate change scenarios, the mean annual air temperature shows an increase from 1.47°C (B1) to 2.11°C (A2) in the future as compared to the baseline (1990-2010). The mean total annual precipitation also shows an increase from 35.4 mm (A2) to 63.8 mm (B1) in the same period. The results show that in the A2 scenario, the average annual discharge rate decreases by 24% in the future, while in the B1 scenario it increases up to 10% in the same period. According to the B1 scenario, an increase in total runoff is predicted. Although in the A2 scenario total runoff will decrease, the average number of days with heavy precipitation will increase. To cope with such changes, the drainage capacity must be increased. To reduce sediment transport and contaminants adhering to it, new approaches such as buffer strips should be considered. Finally, it is recommended that other scenarios that are more adaptable to the region's future conditions such as land use changes also be investigated.

**KEY WORDS:** Climate change, Surface drainage, SWAT Model, LARS-WG, Ilam dam watershed

# CONTROLLED SUB-SURFACE DRAINAGE AS A STRATEGY FOR IMPROVED WATER MANAGEMENT IN IRRIGATED AGRICULTURE OF UZBEKISTAN

Victor Dukhovny [1],Shavkat Kenjabaev [2,*],Shavkat Yakubov [3], Gulomjon Umirzakov [4]

**ABSTRACT**

An existing conventional subsurface drainage system (CVD) was modified to control the flow from the drainage lateral and to control the groundwater table depth in portion to the irrigated winter wheat field during the 2014-2015 crop growing season in the Fergana valley, Uzbekistan. Drainage outflow at the one out of two drainages was controlled (CTD) while the other was left free (CVD). Drainage water volumes and water quality were monitored from October 25, 2014 until June 15, 2015. The cumulative drainage water volume from the CVD treatment was 22% greater than the CTD treatment over this period. The flow weighted mean salt concentration of the drainage water was 7% lower at the CTD treatment (2.08 mS cm−1) as compared the CVD treatment (2.24 mS cm−1). In addition, the effect of CTD experiment on crop growth parameters as well as on grain yield was evaluated by comparing a ratio of the field level hydraulic parameters between transects #A and #B (1) vs. #B and an open collector (2) along the

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drainage course. The ratio of soil water content in the 1 m soil profile between (1) and (2) was 1.20 which indicated that the upper part of the field contained 20% greather soil moisture for the crop to utilize during the growing period as compared with the lower portion of the field. Conversely, the ratio of the water table depth between (1) and (2) was 0.78 indicating that the water table of the upper portion of the field was 47 cm (22%) shallower than the lower part. Thus, CTD increased the moisture storage of the soil layer at the upper part of the field as compared with the lower part. Managing the water table resulted in less water stress between irrigation events and increased grain yields in the area with shallowest groundwater. Introduction of the CTD at the farm level has the potential to improve the livelihoods of farmers by reducing costs associated with water application and maintaining agricultural production in water short years as well as reducing collector-drainage water outflow.

**KEY WORDS:** Controlled drainage, Groundwater table, Drainage outflow, Wheat yield.

# DRAINAGE WATER MANAGEMENT BY FUZZY ANALYTICAL HIERARCHY PROCESS MODEL FOR THE DECLINE OF DRAINAGE WATER VOLUME

Mahboobe Ghasemi [1,*], Abdolrahim Hooshmand [2], Abd Ali Naseri [3]
Gholamhosein Heidar pour [4], Masoud Sayedipour [5]

**ABSTRACT**

In the past decade, major changes in water management in arid and semi-arid areas have emerged. Previously, the focus was on the design and management of irrigation systems and subsurface drainage to compensate for shortcomings. A result of the previous design was high deep percolation losses which led to greater than necessary drainage. The selecting of the depth of drains in the past resulted into large spacing between the drainage pipe and saved costs. These systems reduced cumulative salt in the root zone, causing the low quality water to flow into groundwater sources. To minimize the short-term and long-term detrimental effects of drainage water on the environment, plant products, soil fertility and water quality, in addition to paying attention to the decline of drainage water volume issues is important. Hence, the aim of the present study is to prioritize and assess influencing factors in

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prioritizing the preference of drainage water management specialist using fuzzy AHP.

Analytical hierarchy process (AHP), multi-attribute utility theory, outranking theory and goal programming are among the most common used multi-criteria methods. Although AHP has had a great potential in the evaluation of multi criteria options, it is not compatible with existing uncertainties in paired comparisons and their effect in the selection process. Therefore, in recent years, the application of of Multi-criteria decision-making methods has been expanded. Fuzzy multi-criteria decision making methods are combined with fuzzy logic and multi-criteria decision processes. The numbers used in this procedure are fuzzy triangular numbers. In this study, water conservation, Drainage water reuse, drainage water disposal and drainage water purification were reviewed. The model includes the steps of problem definition, calculation, and ranking of drainage water management options and fuzzy hierarchical structures that encompass three targets, in addition to the main criteria and sub criteria. In order to select the criteria, sub criteria and factors and determine the relative importance of each of them, researchers and experts' opinions, as well as a summarizing of the results of the questionnaire were used. In the next step, using Chang's extent analysis, various water management options based on the criteria and sub criteria and selected factors were evaluated. The results show that water conservation is the most important option in drainage water management. Among the sub criteria water conservation, and source reduction are the highest priority. Among the main criteria of drainage water management the second priority is placed on the reuse of water. Among its sub criteria wildlife and wetland criteria, with a weight factor of 0.260 is the most important. Sequential use of drainage water criterion of with a weight factor of 0.248 is the second priority.

The treatment and disposal of drainage water are the third and fourth priorities respectively. Among the disposal of drainage water sub criteria, draining into oceans and salt lakes are the best options. The physical – chemical index among drainage water treatment options with a weight factor of 0.605 has a higher priority than the biological index.

**KEY WORDS:** Drainage water management, Fuzzy hierarchical analysis, Resource conservation, Reuse of drainage water, Sequential use of drainage water.

# THE TENDENCY OF DRAINAGE RUNOFF IN CLIMATE CHANGE CONTEXT

Otilija Miseckaite [1,*], Alexander A. Volchak [2]

**ABSTRACT**

The present article analyzes the change of climatic conditions in the Central Lithuania. Meteorological conditions in 1969–2009 were studied while analysing changes in seasonal distribution of the average air temperature and precipitation amount in Central Lithuania during the period of four decades, meanwhile complete studied period was divided each ten years. The activity of drainage during various seasons and the impact of meteorological conditions on drainage runoff in different seasons (winter, spring, summer and autumn) are reviewed.

**KEY WORDS:** Drainage, Runoff, Precipitation, Temperature, Climate.

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# THE EFFECT OF CLIMATE CHANGE ON THE QUANTITY AND QUALITY OF AGRICULTURAL RUNOFF (CASE STUDY: GOLGOL RIVER BASIN)

Bahman Moshtaghi [1,*], Sepehr Dalilsafaee [2]
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**ABSTRACT**

Nowadays, the effects of climate change due to global warming and changes in precipitation patterns is quite evident. The increase of greenhouse gases has had an extensive negative effect on almost all regions of the Earth and on different systems, such as water resources, the environment, agriculture, industry, and health. Climate change and global warming have caused an intense deficiency of available potable water. This deficiency can decrease the quality of water as well. One of the prominant effects of climate change is on agriculture and water. Changes in demand for agricultural products can affect water resource management seriously. The reuse of agricultural runoff in areas facing water deficiency is important. A study was carried out in the Golgol River Basin. This river is one the main sources of the Ilam reservoir dam. Nearly 27 percent of the total basin area is under irrigated and rain-fed cultivation. In the case of rain-fed cultivation, wheat and barley are dominant crops. In this basin, wheat and corn are often grown under irrigated cultivation.

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Using fertilizers, which may have a significant impact on the quality of runoff. In order to predict temperature and precipitation under the effect of climate change, using the output of a HadCM3 model under the A2 emission scenario for two future periods (2046-2065 and 2080-2099) were used. The scenario of high population growth and a lesser dependency on economic development has been used on a regional scale in order to determine the amount of greenhouse gases. The LARS-WG model was used for downscaling. The results show that the temperature increases during the two periods and also changes in precipitation is observed. In order to simulate the runoff, an organic nitrogen and nitrate hydrological model (SWAT) and for calibration, SWAT-Cup and Sufi2 method were applied. Introducing downscaled results of AOGCM models to the hydrological model and assuming similar regional conditions including fertilizer and land use, changes in runoff and pollutants in the future were also simulated. It was observed that during 2046-2065, the average monthly Runoff, Nitrate and Organic nitrogen loads would decrease by 27, 18, 13.5 percent. 2080-2099 period when compared to the present, show that the average monthly Runoff, Nitrate and Organic nitrogen loads would decrease by 45, 33, 35 percent. To prevent economic and agricultural losses and concerns about the decrease in the quality of water resources, runoff management might be required in the future.

**KEY WORDS:** Climate change, River water quality, Agricultural runoff, SWAT, LARS-WG.

# 2

# Topic 2:
# Measures to Improve Drainage Water Quality

# MODELING NITRATE-N LEACHING IN NO-TILL FIELDS WITH DRAINMOD-N II

Seyyed Ebrahim Hashemi Garmdareh [1,*], Raheleh Malekian [2], Ali Madani [3], Robert Gordon [4]

**ABSTRACT**

Conservation agriculture, especially no-tillage, has proven to result into sustainable farming in many agricultural environments globally. In spite of some advantages of no-till systems, this practice may increase infiltration into the soil and leaching to groundwater. This method can also enhance the movement of mobile nutrients and some pesticides to subsurface drains and to deeper groundwater along preferential pathways in the soil profile. In this study, DRAINMOD-N II was utilized for the simulation of nitrate-nitrogen (NO3-N) concentration in till drainage water outflows in no-till filed of Truro, Nova Scotia, Canada from2003-2006. The model performance was evaluated first by comparing the observed and simulated drain outflow data that is an essential prerequisite for the model to obtain a proper prediction of NO3-N movement, and then by comparing the observed and simulated NO3-N concentration in no-till fields using three statistical indices, relative root mean square error (RRMSE), average absolute deviation (AAD) and the correlation coefficient (R2). The RMSE, AAD and R2 for validation period were determined to be 1.09 mm, 1.85 mm and 0.83 for drain outflow, and 1.43 mg/l, 0.51 mg/l and 0.79 for NO3-N concentration respectively. The results showed that DRAINMOD-N II predicted reasonably well NO3-N leaching in drainage outflow of no-till fields over the whole years.

**KEY WORDS:** No-till, DRAINMOD-N II, Nitrate, Leaching.

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# IMPACT OF DRAINAGE EFFLUENTS ON GROUNDWATER QUALITY- A CASE STUDY FROM LAHORE PAKISTAN

Ghulam Zakir Hassan [1,*], Faiz Raza Hassan [2], Saleem Akhtar [3]

**ABSTRACT**

In Pakistan, approximately 80% the population in large cities do not have access to clean water. Lahore the provincial capital is the second largest populated city of Pakistan with an estimated population of 10 million people and an area of 1014 km2. It is located on the alluvial plain of the Indus Basin on the left bank of the Ravi River. The Water and Sanitation Agency (WASA) is pumping groundwater at a rate of 1400 MCM per annum to meet the domestic needs of the city. Different drains are discharging domestic, industrial and agricultural effluents in the River and polluted water of the River is leached to underground reservoirs. To evaluate the impact of this pollution on underlying groundwater, an experimental setup has been developed in 2010 along the River. Fifty piezometers in the shape of three batteries perpendicular to the River, one just on the River edge, the 2nd at a distance of 500 ft. and the 3rd at a distance of about 1500 ft from the River bank have been installed on both sides of the River at three sites, covering a length of about 60 km of the River. Each battery consists of three piezometers at 50ft, 100ft and 150ft depth below ground level. The four dimensional (along the river, across the river, vertically downward and with respect to time) trends of groundwater levels and quality are being monitored

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and evaluated. The analysis of data observed so far indicates that groundwater quality is deteriorating with the passage of time especially at the Shahdra Bridge site (near Lahore). It has been further observed that pollution in the River Ravi is contributing to the deterioration of groundwater quality. Fluctuation of groundwater levels measured using a river gauge indicates that the River is hydraulically connected with the aquifer and is recharging it. Groundwater levels in the aquifer of Lahore are falling at an average rate of 2.5 ft. per year mainly due to excessive pumpage and less recharge due to urbanization. Groundwater quality deteriorates moving downward from Ravi Syphon to Mohlanwal and is the worst near the city and improves at the depth below the natural surface. Sub-soil strata at most of the sites are generally sandy except a thin layer of clay/silt in the upper layer at 50 ft. The slope of groundwater seepage line at Shahdra on the left side of the River is steeper as compared to the right side due to excessive pumpage of groundwater in the city area. Keeping in view the current situation some possible measures for the management of groundwater have been recommended in the current study.

**KEY WORDS:** Groundwater, Piezometers, Effluents, Ravi River, Artificial recharge, Lahore.

# IDENTIFYING AND DETERMINING POLLUTION LOAD OF AGRICULTURAL POLLUTANTS IN THE CATCHMENT BASIN OF KARUN AND DEZ RIVERS

N. Hosseini-zare [1,*], N. Shahinzadeh [2], D. Bahmaei [3]

**ABSTRACT**

The impacts of climate change and human induced activities due to the development of urbanization, industries and agriculture are the biggest challenges in the field of water resource management in Iran, especially river water management in Khuzestan Province. Suitable soil and water resources in the Great Karun River basin, extensive areas of natural resources, favorable climate conditions and energy resources have led to the development of agriculture, industry, and population growth in the Karun and Dez Rivers margins. This study aims to identify, quantitatively and qualitatively review and determine the pollution load of agricultural drainages in the basin of Great Karun (Karun and Dez Rivers), determine the volume of drainage water and the impact on the quality of production resources. After field study, sampling (N=96) was done during four seasons in 2013-2014 in 24 input points of drainage water to water sources. The EC, pH, TSS, NO3-, DO, BOD, PO4-3, COD features, Cations, Anions and discharge were measured. Results showed that agricultural pollutants with a volume of 2,374 million cubic meters per year are causing pollution of types TDS and NO3- with 11862 and 65.51 tons per day, respectively.

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Pollution load of organic materials based on BOD and COD is 29.7 and 211 tons per day, respectively. Results also showed that, the Dez river reach has the largest share in terms of volume of drainage water and incoming pollution load. Moreover, the agricultural drainages of Shoeibieh, Haft –Tapeh Sugar cane, Ajirub and Salimeh, Karun (K), Myanab and Kharur within the Dez river reach, the drainages of Sardarabad (N) and Zahuabad within the Shatit reach and the fish-farming wastewaters within the Gargar river reach are among the most important drainages affecting the quality of water resources and agricultural lands in the downstream basin. Evidences show that in future the situation will be worse if proper measures are not undertaken.

**KEY WORDS:** Pollution load, Karun and Dez rivers, Soil and water resources, Agricultural drainages, Khuzestan

# APPLICATION OF BIO-DRAINAGE SYSTEMS FOR THE SUSTAINABLE AND OPTIMAL USE OF IRRIGATED LANDS AND THE PREVENTION OF THE SALINITY AND OVER-DRAINAGE OF ARABLE LAND

Mehdi Khajeh Poor [1,*], Sara Khoramzadeh [2]

**ABSTRACT**

Sustainable agriculture in irrigated lands requires a natural or artificial drainage system which will extract the surplus water and salt from the soil. In many regions the natural drainage system fails to be efficient enough and artificial surface or sub-surface drainage systems must be implemented which in themselves are not only costly but also cause environmental problems in the area itself. It is believed that in such areas other methods for the transferring of salt and excess water off the land should be applied. One of the modern methods applied currently is that of bio-drainage which along with dry drainage and Argo-forestry are used for the reducing of environmental damage to drainage sites. In this paper, the author shall be focusing on the application of bio-drainage in the Khuzestan region. The main objective was the sustainable and optimal use of irrigated land in order to prevent the over drainage and salinity of the arable lands in the region. In contrast to artificial drainage systems which rely on mechanical equipment, in bio-drainage systems plants are used for the controlling of salinity and the retaining of the static equilibrium. Plants with the capability of dynamic absorption and transpiration pump groundwater upwards and release it to the atmosphere. This is an economical and assured method for the resolving of drainage problems in arid and semi-arid regions. The efficiency of this method in the controlling

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of salinity and excess water depends on variables such as the climate of the region, the soil characteristics, type of crop, irrigation method, and the chemical quality of the water used for irrigation. This method is often successfully applied in zones which have a high static equilibrium along with high rates of transpiration. Studies have validated its effectiveness in retaining the static equilibrium in various zones, yet its effectiveness in the decreasing of the salinity of the soil over a long period of time is debatable. It is believed that this method could prove to be a means of diminishing the effects of saline water on soils, and act as a retardant until more effective salinity mitigation measures are put into place. The amount of land required for the creating of bio-drainage systems is less than ten percent which in comparison to the amount of land required for the creating of an artificial drainage system shows a negligible difference. In the development of this type of drainage system one should consider the following; first of all the plants selected should have the capability to thrive in such an environment and the amount of water they consume and their transpiration index should be high. The plants utilized should be beneficial and have sufficient yields while being saline resistant. The root dispersion should be vertical and deep in order to tap groundwater sources. More over the plants selected should match the crop patterns publically acknowledged by farmers and the environmental effects of the plants should be carefully evaluated prior to implementation. This is largely due to the fact that the best way to protect and preserve such plants is through public awareness.

**KEY WORDS:** Bio-drainage, Irrigated land, Saline soils, Static equilibrium, Soil characteristics.

# ASSESSING SENSITIVITY OF PADDY RICE TO CLIMATE CHANGE IN SOUTH KOREA

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Syewoon Hwang [5], Min-Won Jang [6,*]

**ABSTRACT**

Paddy rice constitutes a staple crop in Korea. This study conducted a sensitivity analysis to evaluate the vulnerability of paddy rice to future climate change, and compared temporal and regional characteristics to classify regions with unfavorable water balances. The ratio of consumptive use and effective rainfall (REIP) was used as a sensitivity index. Weather data from 1971 to 2010 and future climate change scenarios RCP 4.5 and 8.5 were used to evaluate the sensitivity. The results showed an overall increase in water requirements and consumptive use. The REIP values were small for every period, except the 2040s, 2060s, and 2080s under scenario RCP 4.5, and the 2040s and 2080s under scenario RCP 8.5. Both climate change scenarios showed high sensitivity in the regions Jeollabuk-do, Jeollanam-do, and Gyeongnam-do. However, regions Gyeonggi-do,

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Gangwon-do, and Chungcheongbuk-do had low sensitivity as compared to other regions. The REIPs were used to categorize sensitivity into four categories: low consumption-water rich, low consumption-water poor, high consumption-water rich and high consumption-water poor. The Gangwon-do region had the highest number of regions that changed from the low consumption-water rich category to the high consumption-water poor category, making it a priority for measures to improve its adaptive capacity for climate change.

**KEY WORDS:** Climate change, Irrigation, Paddy, Sensitivity, Water vulnerability.

# MODELING THE IMPACT OF DRAINAGE DESIGN PARAMETERS ON THE AMOUNT OF NITROGEN LOSSES IN TILE-DRAINAGE SYSTEMS: A CASE STUDY FROM SOUTHWEST IRAN

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Adnan Sadeghi-Lari [3], Hamed Nozari [4], Mohammad Shayannejad [5]

**ABSTRACT**

Excessive soil nitrogen losses as a result of the inappropriate design of subsurface drainage systems have given rise to different environmental problems. The drain spacing and depth play a substantial role in the quality and quantity of the drain outflow into the environment. In this research, a simple but comprehensive simulation model using a system dynamic approach for the water and nitrogen cycle was used to simulate the impact of drain depth and spacing on nitrate and ammonium losses in sugarcane farmland at Imam Khomeini agro-industrial Company. Sixteen scenarios were modeled including the combination of four drain spacing (60, 70, 80 and 90 m) and four different drain depths (1.1, 1.4, 1.7 and 2.0 m) to compare the effect of drain spacing and depth on the amount of ammonium losses through runoff, nitrate and ammonium losses through drainage water, nitrogen losses via the denitrification process and nitrogen

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uptake by the plant. The results indicated that through the increasing of drain spacing and the reducing of drain depth nitrogen losses in the form of denitrification and runoff would increase; and the nitrate and ammonium losses through the drainage water would decrease. Furthermore, the amount of applied urea fertilizer has a significant impact on the amount of nitrogen losses. So, based on the results the optimal tile-drainage system density in this region would be a drain spacing of 80 m and depth of 1m, in as such that the total drainage and runoff losses would be reduced up to an acceptable level. Therefore, the optimum design of subsurface drainage systems based on environmental criteria could aid in the control of nitrogen pollution on the farm-level.

**KEY WORDS:** Drain depth, Drain spacing, Nitrogen losses, Drainage water, Sugarcane, Imam Khomeini agro-industrial Company.

# RECONSTRUCTION OF RECLAMATED AREAS DRAINED BY PIPE DRAINING SYSTEMS

Yuri G. Yanko [1,*]

**ABSTRACT**

According to monitoring of drainage systems data, regardless depreciation guidelines, the main elements of pipe drainage systems are efficient and are able to significantly prolong effective work of systems with the help of pipe line flashing. Impartial assessment of drainage systems can be obtained on the basis of systematic monitoring which is part of extended monitoring of meliorated lands. On practice, monitoring is based on recognition observations and extraction of drainage pipes. In order to prepare planning documentation for repairing and reconstruction of pipe drainage systems, operating set of documents must be analyzed and afterwards detailed monitoring to be performed in accordance with approved methodology. Here with, reasons of soil water-logging and soil type units are being settled, areas with normal conditions and areas with not satisfied quality of drainage are being determined, conditions of exterior parts of drainage systems (soils, wells, filters) are being examined, and also areas for subsequent test drillings are being traced. While stripping of drainage pipes estuarial parts of reservoirs, draw wells and pipe connections, connections of drainage pipes and reservoirs are being examined, reservoirs and drainage pipes conditions, pore space of pipes, filtering materials and back filling are also being examined. Besides depth of drainage systems and their elevation are being determined in order to create measures to eliminate dysfunctions.

**KEY WORDS:** land reclamation, subsoil drainage, humid zone, reconstruction.

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# 3

## Topic 3:
## Adaption of New Design Criteria in Favor of the Environment

# EFFECTS OF VEGETATIVE BUFFERS ON SEDIMENT AND ITS ASSOCIATED POLLUTANTS TRANSPORT AND DEPOSITION

Sina Akram [1,*], Bofu Yu [2], Hossein Ghadiri [3]



**ABSTRACT**

Silt and clay are primary carriers of adsorbed chemicals- especially phosphorus, chlorinated pesticides- and, most metals, and pathogens which are transported by sediment into aquatic systems. Sediments originate mainly from erosion of valuable topsoil of agricultural land. The control of agricultural pollution usually begins with measures to control erosion and sediment runoff.

Grass buffer strips impact overland flow hydraulics and consequently sediment delivery from hillslopes. Mathematical models facilitate the evaluation of performance of grass strips in reducing sediment delivery by simulating and predicting flow characteristics and sediment transport adjacent to and within grass strips. The GUSED-VBS 2 model has been developed to simulate flow, erosion and deposition processes in the upstream area and within grass strips.

The model is capable of estimating the proportion and amount of different sediment size classes in the outflow. The modified Green-Ampt equation was used to simulate infiltration. Gradually varied flow and a kinematic

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wave approximation were used to simulate flow characteristics upstream and within grass strips. The GUEST model was modified in order to use its basic approaches in the sediment transport module for grass strips. Model predictions agree well with measured data from a set of controlled experiments. The sensitivity analysis showed that the initial soil moisture and flow rate were the most sensitive parameters in predicting runoff loss. Increasing the slope steepness and flow rate dramatically decreased the efficiency of grass strips in reducing sediment concentration and sediment delivery.

Comparing the results of the model simulations for different prevalent scenarios showed that the backwater region upstream of dense grass strips is the main region for sediment deposition on low slopes. In agreement with the experimental observations, the model predicted the proportion of coarse particles to be higher in the deposited material upstream of grass strips compared with the deposited material within the grass strip. The efficiency of grass strips in reducing the concentration of sediment is much higher for coarser than finer particles. Grass strips can thus substantially decrease the delivery of fine particles if a significant reduction in runoff (i.e. infiltration) occurs within the strip. As no backwater forms on high slopes and the flow velocity is high in steep lands, particles will not have enough time to deposit ahead of the strip. Having long grass strips can amend the low trapping efficiency associated with extreme conditions such as high slope, wet soil and sparse grass strips by providing more opportunity for particles to settle and more runoff reduction. The new model is a tool to simulate transport and deposition of sediment along with its associated pollutants into the surface drains, rivers, lakes, wetlands and other receiving water bodies.

**KEY WORDS:** Model, Grass Strip, Sediment, Vegetated Strip.

# COMPARISON OF THE BENEFIT FOR APPLYING SHALLOW DRAINAGE METHOD OF FOOD CROPS AND DEEP DRAINAGE OF TREE AT THE RECLAIMED LOWLANDS IN JAMBI-INDONESIA

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**ABSTRACT**

This research focuses on the projection of an irrigated tidal peat-swamp in the Rantau Makmur village, Jambi, Indonesia, in order to assess the impact of peat losses due to the drainage system. Several drainages scenarios were considered carefully to find the best scenario suitable for the region. In order to quantify the impact of drainage, we developed a 3-D (x,y,t) EmSub model. The model can be used to estimate the CO2 emissions due to peat oxidation, as well as the estimating of the subsidence based on soil consolidation and peat losses. Short-term simulation for 4 years showed a good agreement between the simulated subsidence and the observational data. Therefore, the utilization of this model for a long-term projection may be promising. The impacts from various scenarios are investigated using 100 years simulation. The model shows clearly that the deep water table causes more CO2 emission and more subsidence than the shallow water table. Every plant has a different drainage depth. Two groups of plants have been introduced: 1) Tree crops (industry and forestry) which live on deep water table (acacia and palm oil); 2) Food crops which live on shallow water table (paddy). The simulations show that tree crops release abundant CO2 emission and strong subsidence which lead to

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not-usable soils due to inundation. Therefore, profit/loss ratio of food crops drop significantly and is less than tree crops. In general, the model shows that tree crops group (acacia, palm oil, rubber, jelutong) contribute largely to CO2 emission and subsidence. This may be related to the depth of drainage. In addition, high CO2 emission and large subsidence could reduce profit margins significantly. In particular, the highest rate of CO2 emission and subsidence is triggered by acacias, which need a very deep water table. Detailed results and discussions of every plant are shown in this paper. This will help users and decision makers to choose the best scenarios for long-term land management planning in the study area.

**KEY WORDS:** Spatial model, Drainage, Peat swamp, Subsidence, CO2 emission.

# SHALLOW SUBSURFACE DRAINAGE IN PADDY FIELDS: ENVIRONMENTAL CONSEQUENCES AND CROP RESPONSES ANALYSIS

Abdullah Darzi-Naftchali [1,*]



**ABSTRACT**

Increased population along with decreased productive lands due to urban expansion are major challenges of policy makers emphasizing on better use of limited available profitable land resources. Rice production systems in northern Iran which generally experience single crop per year, could be a suitable target for improving self-sufficiency of the country if their drainage problems were controlled in a sustainable manner. On the other hand, drainage should secure sustainable agriculture in the region with less consequences on the fragile environment. A comprehensive- drainage pilot study was conducted on a 4.5 ha consolidated paddy fields of Sari Agricultural Sciences and Natural Resources University, Mazandaran province, Iran, to explore effects of different drainage strategies on crop yields and salt, phosphorus and nitrate losses for developing a drainage system as a new approach. The pilot consisted of 11 shallow subsurface drain lines with 0.65 and 0.9 m depths and 15 and 30 m spacings resulting in three conventional subsurface drainage systems and a bilevel subsurface drainage system. Moreover, the traditional surface drainage of the consolidated paddy fields was included in this study. Two types of water management including mid-season drainage and alternate irrigation and drainage were experienced during 4- rice growing seasons (2011-2015). Additionally, free drainage was practiced during 4- canola growing seasons in the study period. Nitrate and phosphorus losses, salt loads and crop yields were monitored in the growing seasons. Salt loads and

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phosphorus losses were generally higher under shallow drains than deep drains. Under different water management strategies, increase in drainage intensity resulted in more nitrate loss. Subsurface drainage caused gradual improvement in the overall productivity of the study area through increase in rice and canola yield. Based on the results, shallow drainage systems could ensure agricultural sustainability in northern Iran's paddy fields.

**KEY WORDS:** Annual cropping, Nitrogen, Phosphorous, Salt load, Productivity.

# UPSCALING HYDRAULIC CONDUCTIVITY IN SOILS: TECHNIQUES FROM STATISTICAL PHYSICS

Behzad Ghanbarian [1,*]



**ABSTRACT**

Estimating single- and two-phase hydraulic conductivities in soils, particularly in large scales, is essential for designing irrigation systems and drainage networks. Therefore, upscaling hydraulic conductivity K has been a challenge over the years, and rigorous techniques applicable to heterogeneous soils are still required. In the literature, most of the applied methods used for determining an effective and representative value of K are based on weighted arithmetic and harmonic means corresponding, respectively to the parallel (layered soils parallel to flow direction) and series (layered soils perpendicular to flow direction) models. In reality, however, soils, exist neither in series nor in parallel form, but are complex multi-scale networks. In this study it is proposed that techniques, such as critical path analysis and effective-medium approximations from statistical physics to upscale hydraulic conductivity in heterogeneous porous media like soils be considered. The former is valid in strongly heterogeneous media, while the latter is applicable to homogeneous and relatively heterogeneous systems. Advantages and disadvantages as well as practical applications of each method are discussed in details.

KEY WORDS: Critical path analysis, Effective-medium approximation, Hydraulic conductivity, Upscaling.

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# EFFECTS OF CONTROLLED DRAINAGE ON NON-POINT SOURCE DISCHARGE FROM PADDY RICE IN KOREA

Jeong Ryeol Jang [1,*], Kyeung Kim [2], Jung Hun Song [3]
Inhong Song [4], Moon Seong Kang [5]

**ABSTRACT**

The objective of this study was to develop water management practices to reduce pollutant loads and to develop guidelines for paddy rice cultivation. The experimental fields were established at Chunpo-myeon, Iksan-si, in the Saemangeum watershed. The experiment was performed during the growing season to assess water and mass balances of the study field in 2013 and 2015. In this study the two different farming practices were applied: conventional and water treatment. Conventional practices were applied to maintain an average water depth of paddy fields at 7 cm, while the water depth of water treated plots were maintained at 7 cm to midsummer drainage and then raised to 12 cm afterward. Chemical fertilizer was applied in both plots. The water balance analysis indicated that the drainage of water treatment decreases by 24.2% (conventional: 394.5 mm, water treatment: 298.4 mm) as compared to the conventional

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treatment. Drainage when compared to the inflow of water treatment decreases from 0.9% to 9.6% as compared to the conventional treatment. The mass balance analysis indicated that T-N (Total-Nitrogen) drainage load of water treatment decreases by 27.1% (conventional: 1.25 kg/10a, water treatment: 0.91 kg/10a) and T-P (Total Phosphorus) decreases by 38.0% (conventional: 0.125 kg/10a, water treatment: 0.077 kg/10a) as compared to the conventional treatment. T-N drainage load when compared to the inflow of water treatment decreases from 0.5% to 3.3% and T-P decreases from 0.6% to 3.3% respectively as compared to the conventional treatment. The results of this study confirmed that water treatment in paddy fields reduces pollutant loads and could be used as a guidelines for farmers.

**KEY WORDS:** Paddy, Non-point source, Drainage outlet heighten, Water balance, Mass balance

# NON-EXCAVATION SUBSURFACE IRRIGATION AND DRAINAGE SYSTEM IN THE RECLAIMED LOWLAND TO BE CULTIVATED WITH UPLAND FIELD CROP

Hyuntai Kim [1,*], Donguk Seo [2], Jeonyong Ryu [3]

**ABSTRACT**

Although in the past reclaimed land was developed and used mainly as paddy fields in Korea, there is a currently a need to improve the reclaimed land to be cultivated for highland-field crops, due to the necessity for a smooth management of grain supply and demand in order to be able to cope with the changes in the international and domestic agricultural environment, and the earning of a higher revenue from farming highland-field crops instead of rice. However, it is difficult to cultivate highland-field crops in reclaimed land, because it is mostly located in lowland zones containing high salinity soil that is difficult to drain due to the characteristics of fine grained soil which is a major component of reclaimed land. In addition, there is the major problem of re-salinization of root zone soil caused by the capillary rise of saline groundwater during the dry season. In this study, seepage analysis was conducted on each type of subsurface drainage system to draw a high-capacity drainage system, and subsoil breaking and no-excavation subsurface drainage system were proposed to be utilized for the improvement of reclaimed land at low-cost to cultivate highland-field crops. The following results were acquired through pilot construction in the field.

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Reclaimed soil of Korea, which is mostly impermeable (k<1×10-4 cm/s), requires the introduction of 1.subsurface drains and 2.subsoil breaking method, to improve the land to be cultivated for highland-field crop.

In order to array the appropriate spacing (3~10m) by soil type, it is necessary to develop and introduce cost-effective non-excavation subsurface drainage system installation methods.

The introduction of a subsurface irrigation and drainage system is necessary to clean drain systems and to prevent re-salinization.

As a result of the construction of a pilot a cost-effective non-excavation subsurface irrigation and drainage system, it was confirmed that workability improved due to the application of a non-excavation method, whatsmore, construction cost dropped significantly (75%) and subsurface drain and desalinization performance was far superior (over 150%) with 5m intervals in parallel with subsoil breaking method than that of the existing method with 10m intervals.

It was proven that subsoil breaking and subsurface irrigation and drain systems were efficient to clean the drain system using underground irrigation water as well as to prevent re-salinization. And it was also confirmed that the system made the desalinization of soil from 10~15ds/m to 2~5ds/m within a year under the condition of natural rainfall possible. As the result of crop cultivation on the pilot reclaimed land desalinized by subsoil breaking and subsurface irrigation and drain system, it was found that crop growth had a moderately high status without any damage by moisture during the wet season, and it led to the conclusion that the system is highly effective for the development of reclaimed land.

**KEY WORDS:** Subsoil breaking, subsurface irrigation and drainage, Subsurface horizontal filter system, Non-excavation system.

# POTENTIAL OF SUPER ABSORBING MATERIAL IN A SUBSTRATE MIX FOR EXTENSIVE GREEN ROOFS

Farhad Misaghi [1,*], Zeinab Bigdeli [2], Masoud Saeedi [3]

**ABSTRACT**

The application of green roofs is increasingly recognized in many countries as a solution to improve environmental quality and reduce runoff quantity. This study investigates the viability of super absorbing materials in a substrate mix for extensive green roofs, where plants are supported by lightweight growing media (substrate) overlying a drainage layer. In addition, the role of super absorbing materials as a growth medium, drainage properties of the substrate mix containing recycled materials, as well as its susceptibility to erosion and resistance to sliding when placed on a slope were investigated. Therefore, the main aim of this study is to investigate the impact of natural zeolite on rainfall infiltration into the soil, runoff, and soil water storage capacity in green roofs .This study includes the establishment, development, and performance of both grass and sedum model green roofs under simulated rainfall events. It indicates supportive suitability of the substrate mix containing recycled waste materials for plants growth. It is resistant to erosion and slippage and capable of providing good drainage. The results showed that infiltration in zeolite-treated soil is very high and treated soil can reduce drained water volume. In the treatment analysis,

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the highest rate of drained water was recorded as 20.5 (ml) and it was shown that in untreated soil there is a lacks of water as runoff, thus drainage and preserving water in the soils were too low and the lowest rate of drained water was seen in soil treated with 3% zeolite (5 ml).The results of this laboratory investigation were used to extend green roofs into the wider perspective of sustainability benefits.

**KEY WORDS:** Green Roof, Super Absorbing Material, Drainage.

# THE EFFECTS OF DIFFERENT DRAIN SPACING AND DEPTHS ON WATER TABLE LEVEL AND SOIL SALINITY IN HARRAN PLAIN OF TURKEY

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Oner Cetin [3,*], Huseyin Gungor [4], Ramazan Erdem [4], M. Sami Nacar [1]

**ABSTRACT**

Harran plain, totally 225000 hectares, is the first big scale irrigated area in South Eastern Anatolia Project (GAP) in Turkey. This Plain has been irrigated since 1995. Approximately, the part of 50.000 ha in this plain has a high water table which was caused by irrigation, geological-hydrogeological structure. The low quality waters infiltrated from irrigation has raised the water table of the perched aquifer which is resulted in a direct hydrological connection between waters of different quality. Thus, high water table and soil salinization increasingly spread. In this study, some drainage criteria were studied. Different drain spacings and different drain depths on the effects of water table, salinization and corn yield are investigated. Three different drain spacings (45 m, 60 m and 75 m)and three different drain depths (1,2 m, 1,5 m and 1,8 m) were used in this study. In addition, a cross drain pipe was placed between two parallel drains spaced 120 m. In the first year, corn was planted between parallel drains and the same agricultural process has been applied for the whole fields. There were no significantly effects between different

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drain spaces on the crop yields. The depths of water table were ranged from 120 cm to 140 cm during the irrigation season for both of the areas of crosswise drains and different drain spacings and drain depths. The effects of different drain spacings on the salt variation of root zone will be evaluated at the end of the first year and the third year of the study.

**KEY WORDS:** drainage, drain depth, drain space, salinity

# ASSESSMENT OF DIFFERENT LEVELS OF NITROGEN AND CONTROLLED DRAINAGE ON YIELD AND WATER PRODUCTIVITY

Masoud Noshadi [1], Samaneh Karimi [2]

**ABSTRACT**

The growth of world population and demand for agricultural products is a majora global issues. Controlled drainage (CD) is a management technique to control water level for increasing the yield. This research was conducted to evaluate the effect of controlled drainage and nitrogen fertilizer on wheat yield and water productivity as a factorial randomized complete block design. The treatments were consisted at three fertilizer levels; 0, 200 and 300 kgN/ha and three water table depths including control water tables at 60cm (CD60), 90 cm (CD90) and 120 cm (CD120) depths. The results showed that the wheat yield in CD60 was 10% lower than CD120 and in CD90 was 18% more than CD120. The water productivity in CD60 and CD90 was 52.6 and 57.9% more than CD120, respectively. By increasing the values of nitrogen fertilizer the wheat yield and water productivity were also increased.

**KEY WORDS:** Controlled drainage, Fertilizer, Wheat, Water productivity.



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# RAINFALL FREQUENCY ANALYSIS FOR LAND DRAINAGE CRITERIA IN BIHAR - A CASE STUDY

Lal Bahadur Roy [1,*], Ashutosh Upadhyaya [2]



**ABSTRACT**

Irrigation and drainage are complimentary to each other. Normally land drainage is a problem in very flat or level land. Drainage congestion leads to waterlogging. The problem of waterlogging is a world-wide phenomenon which occurs mainly due to the rise of the groundwater table beyond permissible limits. Land subjected to waterlogging has already affected about 3 to 6 M ha of cultivable land in India.

Bihar is an agriculture based state of India and is facing the two problems of floods and droughts. Among the adverse effects of floods is waterlogging in agriculture fields, since there is no adequate land drainage system in the state. In this study, the determining of the effects of one to seven consecutive days of maximum rainfall corresponding to a return period varying from 2 to 20 years and a crop tolerance period, which helps in the determination of a drainage coefficient for agricultural fields, utilizing the daily rainfall data of Patna for the period 1980-2009 has been considered. A positions plotting method and other probability distributions have been applied to estimate one day to seven consecutive days of maximum rainfall over various return periods.

The comparison of these methods, show that Gamma distribution gives the best coefficient for the determination and predicts values closer to the values obtained by the plotting position method. Results also show that for a return period of 2 to 20 years, the plotting position method gives the lowest values of one day maximum rainfall. Drainage coefficient with a bund height as 100 mm and 150 mm have also been determined from depth duration frequency curves.

**KEY WORDS:** Land drainage, Waterlogging, Rainfall frequency analysis, Drainage coefficient, Gamma distribution

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# POLDER DRAINAGE SYSTEM TO MITIGATE VULNERABLE ECOSYSTEM OF COASTAL BANGLADESH

Subrota Saha [1,*], Satchidananda Biswas [2]

**ABSTRACT**

People of the coastal belt of Bangladesh are fully dependent for their comprehensive livelihood on the coastal embankment. Bangladesh Water Development Board (BWDB) constructed an embankment in the 14 coastal districts of Bangladesh. They have made 139 polders since 1960s to grow more food by protecting coastal land from saline intrusion caused by tidal flooding and to ensure the preservation of sweet water in canals for agricultural production in dry seasons. Embankments built to prevent flooding or coastal tidal surge of low-lying land are also called a levees or dykes which are constructed along a riverbank and at some distance from the river to retain floodwater or tidal effect. These embankments provide a protected environment for people's resources. The coastal region of Bangladesh portrays acute socio-ecological complexities, where people are gradually becoming powerless, socio-economically marginalized and vulnerable. The complexity arise through vulnerable coastal and mangrove ecosystem and fluctuating socio-economic life patterns that are caused by a number of ecologically inconsistent developmental intervention and land use practices. There are many natural and man-made hazards like cyclones, embankment erosion, tidal surges, salinity, water logging, floods during heavy rain fall, drought, pests in crops etc. that increase the risk of disaster among the vulnerable community. Under the programme of flood control and drainage improvement, about 7,555 km of embankment

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(including coastal embankments of about 4,000 km), 7,907 hydraulic structures including sluices, and around one thousand river regulators, 1,082 river closures and 3,204 km of drainage channels have been built at the cost of a thousand core taka. Under the scheme a total of 332 projects, aimed at protecting 3.5 million ha of land from flood inundation, have been implemented. Thus, about 24% of the total land area and 39% of the net cultivated area have been protected. However, the success of embankment construction depends technically on the natural detention basin, channel improvements, flow diversions and bank stabilization and anti-erosive measures. The CEP comprises a complex network of dikes and drainage sluices and was the first comprehensive plan for providing protection against flood and saline water intrusion in the coastal area. The function of the embankment depends on many coastal factors of which the most prominent issues were the management of sluice gates, managing canals downstream the sluice gate, operation & maintenance of sluice gate, regular monitoring of the embankment, illegal cutting of the embankment to set pipes for shrimp farming, etc. Here the greatest concern was people's involvement or a community based approach to manage the polder system for embankment & canals in the context of sustainability. The Embankment and Drainage Act 1952 ensures the protection of lands from floods, erosion or other damage by water through the constructing and repairing of the embankment, but it has developed gaps over the years. Sluice gates were also constructed at certain places to control water channeling from the sea /channel to inland canals. But since, 1980s people with money and access to power started taking lease of the water bodies inside Polders to cultivate saline water shrimp farms; and as a result thousands of unplanned cannels were made in the embankment causing it to become thin and weak. Whatsmore, it also excluded poor farmers from accessing and controlling water bodies, causing them to cultivate their land with a single crop. The local government officials now properly understand community demands and feel more accountable to construct and maintain a sustainable embankment.

**KEY WORDS:** Polder, Ecosystem, Mitigation, BWDB, Zaminder, CRA.

# ESTIMATING SOIL HYDRAULIC AND SOLUTE TRANSPORT PARAMETERS IN SUBSURFACE DRAINAGE SYSTEMS USING INVERSE MODELING APPROACH

Amir Sedaghatdoost [1], Hamed Ebrahimian [2,*], Abdolmajid Liaghat [3]

**ABSTRACT**

Due to the time and spatial limitations of subsurface drainage pilots, simulation models have been extensively applied for evaluating such systems. Simulation models are powerful tools which are used for the describing of the interactions between subsurface drainage systems, crop yield and environmental issues. Since the accuracy of simulation models depends extensively on the accuracy of the model inputs, the aim of this study is to present an inverse modeling approach with a genetic algorithm in estimating soil hydraulic and solute transport parameters in subsurface drainage systems and compares it with in-situ determination of soil properties. Inverse modeling is defined as the process of estimating model inputs by matching a forward model to measured data within an optimization algorithm. In this method, sensitivity analysis has a vital role in allowing a possible reduction in the number of parameters that must be estimated, thereby reducing the computational time required for inverse modeling. In this study, measured data was obtained from

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Amirkabir and Shaeibie sugarcane plantations which have subsurface drainage systems. Both studied areas are semi-arid regions with fine-texture soils. The available measured data for Amirkabir site was drainage discharge and salinity while water table depth was also available for Shaeibie site. SWAP model was used for simulating the outputs of subsurface drainage systems. This model simulates transient water flow using Richards' equation including the extraction rate by drain discharge in the saturated zone as sink terms. The accuracy of different objective functions which were based on the discrepancies between measured and simulated values of drainage discharge, water table depth and drainage salinity was evaluated in the inverse modeling approach. Sensitivity analysis of the SWAP model in both studied areas showed that n shape parameter, lateral hydraulic conductivity (Kh), depth to impermeable layer (D), saturated water content (θs), and α shape parameter are the most sensitive parameters in simulating subsurface drainage outputs. Thus, these parameters were selected in order to be determined by the inverse modeling approach. In the Amirkabir study area, minimizing the objective function which is based on drainage discharge and salinity is the most appropriate approach which can determine soil hydraulic parameters. By applying an inverse modeling approach, Nash–Sutcliffe efficiency (NSE) value for predicting drainage discharge and salinity were 0.63 and 0.79, respectively. In Shaeibie study area, minimizing the objective function which included salinity of drainage water and water table depth and also the objective function, based on the combination of drainage discharge, watertable depth and drainage salinity are influential in obtaining soil hydraulic properties that could simulate the outputs of the drainage systems accurately. By using this objective function in determining soil properties, NSE value for predicting drainage discharge, water table depth drainage salinity were 0.83, 0.95 and 0.89, respectively.

**KEY WORDS:** Indirect methods, Soil properties, Simulation, Drainage, Optimization

# THE IMPACT OF REDUCING SUB DRAIN DEPTH ON ESTIMATED DRAINAGE COEFFICIENT AND SALINITY OF DRAINAGE WATER

Vorya Soufiahmadi [1], Mahdi Ghobadinia [2], Ahmad Dehghan [3]

**ABSTRACT**

The drainage coefficient is a determinative criterion in subdrain network design. Over estimation of this coefficient results in congested subdrain network and costly design. On the other hand, underestimation of it may cause a rise in the water table in the root development zone, limiting uptake of appropriate combination of water, air and nutrients by the roots and the reducing of soil workability conditions for agricultural practices. Therefore optimizing the drainage coefficient is done with the objective of preparing the most economical and efficient applicable method, which in addition to keeping the water table at an appropriate maximum level to provide better conditions for the aeration of plant roots,while salinity remains at its highest desirable level in the soil profile, without any salinity build up and plant yield reduction.

Based on the obtained calculations, drain spacing is inversely proportional to the square root of the drainage coefficient. Recently Jahad-e-Nasr Institute, the implementing agency for land reclamation projects in the

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Khuzestan & Ilam provinces is implementing the sub drain network in an area of 550, 000 hectares. In the above said provinces. The drain spacing is determined on the basis of recommended cropping patterns and the calculated drainage coefficients. In contrary with to the designed specifications, the implementing agency has made some changes in the network, ,of which the most important one is the reduction of the depth of lateral installation from an average of 1.5 – 1.7 to 1.3- 1.5 meters. Based on the calculations, as the result of these changes the drain spacing must be reduced by 20%, but, the changes for drain spacing have not taken into account during execution works for installing subdrains.
In this research in order to assess the impact of reducing subdrain depths on the calculated drainage coefficient and drainage water salinity loads, two implemented subdrain network laterals in the Mianab-e-shushtar and Shoeibieh plains with areas of 14000 and 10000 respectively were selected. In order to measure the drainage coefficient and compare it with the calculated drainage coefficient, some parts of the above mentioned plains were selected. In addition, by measuring the water level between the sub drains, the role of drainage for reducing ground water table was evaluated. The findings of the research are as follows:
1-the rise of water table exceeds the allowable design 2-the outflow of laterals were reduced 3-electrical conductivity decreased 4-the final water table dropped from one meter to 89 cm 5- a few days after irrigation the electrical conductivity of drain outflow experienced a reduced trend, yet that of ground water and open collectors showed an increasing trend. 6-Glover-dumm performance index was calculated as 0.035 7-salt outlet index (SEI) was negative and 8-the amount of salt entering the environment decreased.

**KEY WORDS:** Drainage coefficient, Glover-dumm, Salt outlet index, Sub drain depth.

# EGYPT'S FOUR DECADES OF EXPERIENCE WITH AGRICULTURAL DRAINAGE AND FUTURE REQUIREMENTS

M. A. S. Wahba [1,*], M. H. Amer [2]

**ABSTRACT**

In arid countries such as Egypt, irrigation and drainage are essential factors for the sustainability of agricultural production. The need for drainage of agricultural lands in the Nile Valley and the Egyptian Delta was realized once the conversion to the perennial cropping system occured.

Among developing countries, Egypt is considered as a country with subsurface drainage systems extending over large areas th. At the time strategic vision and governmental planning were behind the decision to launch a program to develop drainage infrastructures to cover all the irrigated lands (then about 6 million acres).

The implementation of a phased program starting in 1970 and continuing to cover more than 5.8 million acres up to the present time has been carried out consecutively. The implementation of such a large scale program imposed huge financial, institutional and technical challenges. It also involved significant operational challenges including the necessary implementation capacity and the need to complete the construction in cropped fields without interruption the growing season, mainly for social and economical reasons. Experience has shown that drainage has many effects and multiple impacts that go beyond the sole objective of agricultural productivity.

More than four decades have passed since the government of Egypt

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initiated its present program to develop effective drainage systems to cover almost all the agricultural land. Nowadays Egypt is facing great challenges such as water shortage, drought, water quality deterioration, climate change and its unexpected impacts, all of which are threatening the sustainability of the irrigated crops. This paper identifies and synthesizes the Egyptian experience in the field of agricultural drainage and the future need to cope with global challenges.

**KEY WORDS:** Subsurface drainage, drainage materials, controlled drainage, drainage design criteria, drainage technology, Future Vision and Developments in Drainage

# 4

# Topic 4:
# Application of Alternative Drainage Methods

# SOIL SALINITY CONTROL UNDER BARLEY CULTIVATION USING A LABORATORY DRY DRAINAGE MODEL

Shahab Ansari [1,*], Behrouz Mostafazadeh-Fard [2]
Jahangir Abedi Koupai [3]

**ABSTRACT**

The drainage of agricultural fields is carried out in order to control soil salinity and the water table. Conventional drainage methods such as lateral drainage and interceptor drains have been used for many years. These methods increase agriculture production; but they are expensive and often cause environmental contaminations. One of the inexpensive and more environmental friendly methods that can be used in arid and semi-arid regions to remove excess salts from irrigated lands to non-irrigated or fallow lands is dry drainage. In the dry drainage method, natural soil system and the evaporation of fallow land is used to control soil salinity and the water table of irrigated land. There are few studies about dry drainage concepts. it is also important to study soil salt changes over time because of salt movements from irrigated areas to non-irrigated areas especially under plant cultivation. In this study a laboratory model which is able to simulate dry drainage was used to investigate soil salts

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transport under barley cultivation. The model was studied during the barley growing season and for a constant water table. During the growing season soil salinities of irrigated and non-irrigated areas were measured at different time. The Results showed that dry drainage can control the soil salinity of an irrigated area. The excess salts leached from an irrigated area and accumulated in the non-irrigated area and the leaching rate changed over time. Soil surface salinities of non-irrigated areas increased with time. At the end of the experiment, the increase of the mean soil salinity of the non-irrigated area was 2.81 times more than the increase of the mean soil salinity of the irrigated area. In arid and semi-arid regions where suitable conditions exist, dry drainage can be used as a useful management tool to control soil salinity.

**KEY WORDS:** Barley, Dry drainage, Salt movement, Shallow ground water.

# IN-STREAM WETLAND AS A POTENTIAL LOW COST TREATMENT TECHNOLOGY IN RURAL AREAS

Ashraf El Sayed Ismail [1,*]

**ABSTRACT**

The countries of the Middle East and North Africa region have 5% of the world's population but have less than 1% of the world's renewable fresh water. The region is one of the driest in the world and poorly endowed with natural freshwater supplies. The annual per-capita water availability in 1960 was about 1550 m3 and has fallen by 40% to about 650 m3 today and it is expected to be about 450 m3 in 2025.

Wastewater treatment in Egypt's rural areas as well as in many other countries lags far behind potable water supply. Only urban centers and some larger rural villages possess wastewater treatment facilities. Economics of scale makes conventional wastewater treatment cost prohibitive in smaller more dispersed rural settlements. Domestic wastewater is typically discharged directly or indirectly to drainage canals. This practice has contributed to widespread degradation of drainage water quality, thus negatively affecting the reuse of drainage water plans in Egypt. Several treatment alternatives that vary in efficiency and costs are available. The natural wastewater treatment requires relatively low capital investment when flat land is available at reasonable price. Among the natural treatment systems, in-stream wetland has a high potential for application in rural areas of Egypt where the treatment process takes place within the drain.

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Thus, it needs much less land, which is easily maintained, and which can absorb shock loads with relatively less capital and operational costs. All these features have made in-stream wetland a very attractive option for rural communities. Pilot studies in the Nile Delta drain system were conducted to demonstrate the technical feasibility of the in-stream study and adopt the design criteria suited for the Egyptian environment. One pilot area was selected among several potential sites in the Nile Delta using multi-criteria analysis. Baseline studies have been conducted to collect the data/information required for the design of in-stream wetlands. The studies included an intensive water quality monitoring program, hydraulic characteristics, physical survey, socioeconomic survey, developing public awareness program and others related activities.

The HEC-RAS modeling system is used for the calculation of water surface profiles for steady gradually varied flows of the selected drain. MATLAB software is used to develop an external transport module to simulate the convection, advection, diffusion and decay of different pollutants. A group of 25 numerical runs in a matrix were simulated to test the impact of physical interventions on drain surface water profile, detention time and pollutants removal efficiency. The baselines studies show that the self-purification capacity of the selected drain without any physical engineering intervention varies within a narrow range from 29% to 37% for BOD removal with the treatment of detention time from 6 to 8 hours. The proposed system could have a detention time up to 68 hours using limited physical intervention such as sedimentation traps, weirs and baffles. Simulation of different design alternatives indicate that the removal efficiency of such a system can reduce 60% of BOD and 70% of TSS. Introducing aquatic plants would improve the removal efficiency especially for nutrients and pathogens. The performance of the in-steam wetland treatment system under similar conditions in Egypt is expected to be equivalent to the advanced primary to secondary conventional treatment.

**KEY WORDS:** Drainage water reuse, Natural treatment system, Water quality modeling.

# ENVIRONMENTAL CAPABILITIES AND CONSTRAINTS OF HALOCULTURE: ALTERNATIVE STRATEGY TO USE SALINE WATERS IN MARGINAL LANDS

Farhad Khorsandi [1,*]

**ABSTRACT**

Disposal of saline agricultural wastewaters is a complex environmental challenge for agronomists and irrigation managers. The rise in world population, shortage of premium agricultural lands, and scarcity of fresh water resources, particularly in arid regions, makes it necessary to use non-conventional saline water resources and marginal lands to meet the escalating demand for food and drinking water needs. Haloculture offers a strategy for sustainable use of highly saline soil and water resources to provide some of the future human needs. Haloculture is sustainable production of different agricultural and industrial products in saline environments. A saline agricultural drainage water Haloculture agro-industry model is presented, which serves as an economic option for their reuse, and thus, reducing their negative environmental impacts. Along with development of strategies for sustainable and profitable production of bio-products, Haloculture also emphasizes on providing energy and drinking water as the basic needs of rural societies who are going to implement those strategies in less developed, salt affected regions. Haloengineering is briefly introduced as a complementary component of Haloculture. Various activities in Haloculture depends on the input of waters with different salinity levels. Thus, a new guideline for utilization of saline waters in Haloculture is presented. Several cases of Haloculture projects with various degrees of success and failure operated nationally and internationally. The mega project on Haloculture

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undertaken by Iran Water and Power Resources Management Company in four southern coastal provinces of Iran, are described in more details. Haloculture is recommended in areas where conventional agriculture is not physically and/or economically feasible. Environmental stewardship is an important component of a sustainable production system. Thus, the main objective of this article to evaluate the environmental services and constrains of Haloculture. Haloculture has significant environmental potentials in salt-affected arid regions, in terms of combating desertification and erosion, sustainable use of agro-biodiversity, restoration of rangelands, remediation of degraded lands, and greening of coastal areas, reforestation of marginal and degraded lands, restoration and rehabilitation of wildlife and marine habitats, and carbon sequestration. Possible environmental constraints of Haloculture should be considered in development of Haloculture projects. The main possible negative impacts of Haloculture on environment are escalating soil salinity, introduction of invasive exotic plant and aquatic species, degradation of local ecosystem, and possible adverse effects of saline water irrigation on ground water quality. Development of Haloculture projects in previously undeveloped inland salt affected regions and coastal zones, should be done with thorough ecological and environmental impact assessment.

**KEY WORDS:** Biosaline agriculture, Desalination, Drainage waters, Haloengineering, Halophyte, Haloventure, Saline aquaculture, Seawater agriculture

# A STUDY ON CAPILLARY RISE IN CONTROLLED DRAINAGE SYSTEM AND ITS COMPARISON WITH UPFLOW MODEL

Arash Mohammadbeigi [1,*], Farhad Mirzaei [2], Negin Ashraf [3]

**ABSTRACT**

Water flowing upward through the capillary pores of the water table in unsaturated soil is defined as capillary rise and it depends on the water table depth, evapotranspiration and the soil type. Controlled drainage is an appropriate management strategy to control the water table. In the present study, the capillary rise of two soil textures was measured in a number of controlled drainage systems. The rate of capillary rise was estimated using a model. The results show that the estimation of the model is in agreement with the measured values. In loam soil at depths of less than one meter, capillary rise with a relatively gentle slope increased; however when the depth of the water table is too low, it reaches potential evapotranspiration. In depths more than one meter, the capillary rise decreased with a steep incline. In depth of more than 6 meters, the capillary rise is actually close to zero. Constant upward flow of water into the soil surface is in balance with evaporation demand; therefore, it can be used to estimate the amount of irrigation water from shallow water tables.

**KEY WORDS:** Controlled drainage, Capillary rise, Upflow.

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# INVERSION OF PEAT SOIL: AN ALTERNATIVE DRAINAGE METHOD?

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**ABSTRACT**

Many grasslands in Western Norway are situated on former bogs, posing agronomic and environmental challenges for crop production. Histosols with an intermediate (Hemist) or high (Saprist) degree of humification are challenging to drains, especially in areas with high precipitation in the boreal climatic zone. In peat soils the infiltration of water is low whereas waterholding capacity is high. Slow drying and loose physical structures make peat soils easily compacted by tractor traffic. Peat soils are traditionally tile-drained, but due to the aforementioned conditions, the efficiency of the drainage system is often reduced significantly shortly after operations.

In some regions of Norway, tile-drained peat soils are situated on top of a self-draining mineral soil covered by a thin layer of impermeable mineral soil. In such situations, peat inversion can be an alternative to a better drainage method. Inversion means that peat soil is covered with

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the underlying mineral soil while maintaining connectivity to the self-draining subsoil by means of tilted mineral soil layers. The objective of the present study was to investigate the effect of peat inversion relative to tile-drained peat on grassland yield, soil physical properties, greenhouse gas (GHG) emission and profitability.
Preliminary results from a field experiment in Norway suggest that the inversion of previously tile drained peat increases grassland yield. Mean dry matter yield for the years 2014-2016 was 9.3 and 10.95 t ha-1 on inverted and tile-drained peat, respectively. Top-soil physical properties of the inverted peat differ fundamentally from those in tile-drained peat and resembled mineral soil; moreover, inversion also lowered the water table. GHG emissions during the growing seasons were less in inverted than in tile-drained peat. In 2015, this was due to a very large emission of methane (CH4) from the tile-drained peat (4050 kg CO2 eq.ha-1). In 2016 both CH4 and nitrous oxide (N2O) emissions were much less in inverted than in tile-drained peat. Cumulative emissions in 2016 were -60 kg CO2 eq. ha-1 CH4 and 3000 kg CO2 eq. ha-1 N2O from inverted and 1500 kg CO2 eq. ha-1 CH4 and 9000 kg CO2 eq. ha-1 N2O from tile-drained peat. The large variation between the years could be attributed to weather conditions. In summary, the data from our field experiment suggests that the inversion of previously tile drained peat in boreal climates can lower the water table, improve soil physical properties, increase grassland yield and reduce CH4 and N2O emissions.

**KEY WORDS:** Grass yield, Soil physical properties, GHG emissions.

# BIODRAINAGE: AN ALTERNATE DRAINAGE SYSTEM TO MANAGE WATERLOGGING AND SALINITY

Gurbachan Singh [1,*], K. Lal [2]

**ABSTRACT**

In the absence of the provision of adequate drainage, waterlogging and associated soil salinity become major impediments to the sustainability of irrigated agriculture. Though, conventional engineering drainage technologies such as subsurface or vertical drainage are able to combat the problem, yet these methods are costly and generate huge quantities of drainage effluent which result into disposal problems. These conventional options are quite successful where large tracts of land are affected by waterlogging and a continuous salinity exists Biodrainage, which removes the excess soil water via deep rooted fast growing trees through evapotranspiration using bio-energy is proposed as an alternate to the abovementioned engineering approaches. Irrigation of high transpiring forest species has also been put forward for reuse of wastewater and the conservation of nutrient energy into biomass and thereby bringing multiple benefits such as fuelwood production, carbon sequestration, environmental sanitation and eco-restoration. Biodrainage potential of perennial vegetation in general and trees in particular is a cardinal component for designing and implementing biodrainage projects. Consumptive water use of plants varies with the age, geometry, soil properties, water table,

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salinity and climatic conditions. This varies between 6500 to 28000 m3 ha-1 year-1 and under ideal conditions, a tree canopy may lower water tables by 1–2 m over a time period of 3–5 years. Trees of the genes such as Eucalyptus, Populus, Casuarina, Dalbergia, Syzigium, Acacia, Prosopis, Leucaena etc. are reported as being effective to lowering a shallow water table and reverse salinity trends. Amongst different trees studied at different places, Eucalyptus was preferred because it grows fast in a wide range of conditions, grows straight thus creating a low shading effect on associated crops, and has luxurious water consumption in excess soil moisture conditions. Small and marginal farmers may not be able to set part of their farm aside for bio drainage activities therefore biodrainage technology may be more suitable on large farms or public lands. However, integration of trees such as Eucalyptus and Populus along with crops in a unified agroforestry system or on approach roads or field bunds or on dykes of ponds in an integrated farming system will be a viable preposition. For effective understanding and implementation, several case studies on the role of biodrainage for managing waterlogging and salinity are discussed in this paper.

**KEY WORDS:** Salinity, Water logging, Eucalyptus, Irrigated agriculture, Biodrainage, Case Studies.

# SIMULATION OF WATER FLOW AND SALT TRANSPORT IN DRY DRAINAGE WITH HYDRUS-2D

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**ABSTRACT**

Sustainable agriculture can help food security. It depends on water and salt balance in the root zone especially in arid and semi-arid regions of the world. Irrigation without drainage is not sustainable. Dry drainage (DD) is rather a new environmentally friendly concept in drainage of arid and semi-arid areas where the irrigation water is much less than the amount to satisfy the extent of the available land. DD was investigated at this study as an environmental and cost-effective alternative technique to the conventional systems. This study was carried out at University of Tehran, Iran, in July 2015 in Lysimetric scale. HYDRUS software was used for DD modeling. Parameters of water flow and salinity transport were optimized by inverse solution of HYDRUS. Results showed that DD could decrease and stabilize soil salinity of the root zone. The salinity at different soil

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layers of uncropped strips (evaporation strips) was higher than the salinity of cropped strips. Soil salinity at cropped strips was increased downwards while the soil salinity of uncropped strips was increasing upwards. Final soil surface salinity of cropped strips was 1.5 times of the irrigation water salinity while salinity of the soil surface at uncropped strips was reached to 4.5 times of its initial condition after one season. Standard Error and RMSE of observed and simulated volumetric soil water content were 0.26 and 0.104, respectively. Soil salinity of cropped area was predicted better that uncropped area. SE and RMSE of observed and simulated soil salinity were 0.29 and 2.26 (dS/m), respectively. Results of modeling showed that salinity of soil surface at uncropped area was decreased with the passage of time, while surface soil salinity of cropped area remains at its equilibrium.

**KEY WORDS:** Dry Drainage, Evaporation strip, Solute transport, Sustainable agriculture.

# 5

# Topic 5:
# Irrigation and Drainage Management

# DRAINAGE SYSTEM IN IRRIGATED SECTOR KEY FOR BETTER WATER MANAGEMENT GEZIRA SCHEME – SUDAN

Mufadal E. M. Ahmed [1,*], Abu Obieda B. Ahmed [2]

**ABSTRACT**

Agriculture remains a key element and pillar of Sudanese life, and represents the main driving force for its economy and as an income generating sector for more than 50% of households. This sector accounts for about 31% of GDP (Central Bank of Sudan CBOS-report, 2015); The irrigated subsector as part of the agricultural sector is responsible for the production of cash crops (cotton and sugar cane,..) and cereals. In mega irrigation schemes such as the Gezira Irrigation Scheme (GIS)-the forerunner of all major schemes in Sudan with an area of about 0.882 million ha-the drainage (surface) system plays a significant role in tandem with the irrigation system. Water logging and hence the significant reduction in crop production, coupled with negative environmental impacts are considered as strong obstacles against harnessing the available water resources for better livelihoods.

This paper is a contribution to the Sudaese governmen's effort towards upgrading GIS. The drainage system within the scheme did not receive enough attention and witnessed severe deterioration due to several reasons that occurred over the operational lifetime of the scheme, which in itself accelerated the spread of silt and weeds in the network system of the scheme.

The paper discusses and attempts to diagnose, and analyze the performance of the GIS drainage system by identifying its arrangement, design,

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capacities, and adequacy to contribute a solution to water management and constraints to sustainable development. In addition it provides a set of amendments and improvements to the existing system including a revision of its design criteria and how that improvement, if implemented properly, can result in better water management and providing an environment for production.

**KEY WORDS:** Surface drainage, Water logging, Design criteria, Gezira Irrigation Scheme, Water management

# OPERATION AND MANAGEMENT PRACTICES OF DRAINAGE AGRICULTURE UNDER THE LOWLAND AREAS IN INDONESIA

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**ABSTRACT**

Drainage agricultural development and management in Indonesia has recently been conducted by the government since 1960s. This was implemented by means of reclaiming the lowland areas with open drainage facilities for achieving several objectives among others such as the increasing of the national production of rice as a staple diet of the people, with some scattered coconut and palm oil plantation interspaced. Initially this effort was geared toward supporting the achievement and sustaining food self sufficiency, apart from providing agricultural land for involuntary transmigration population resettlement in order to support the Government Program, as well as resolving the vast decreasing of conventional irrigated agricultural lands due to the fast population explosion followed by the rapid land conversion from well developed irrigation areas to urban, industrial and other purposes.

Out of the total 162.4 million ha of potential agricultural land in the f Indonesian Archipelago, about 20.56% consists of lowland areas (tidal and inland areas) and are extended along the eastern coast of Sumatra, West, South and Central Kalimantan, Sulawesi and Papua are major islands with a total area of about 33.393 million ha of which 60% consists of tidal lowlands ( about 20.096 million ha ) and about 40% are the inland non tidal area (about 13.6 million ha), most of which are lowland schemes that are currently in the second development stage. The subsequently developed open drainage schemes are therefore currently demanding for

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sustainable operation and maintenance techniques.
This paper intends to discuss the problems, constraints and future prospects of agricultural drainage development and management with a special focus on operations and maintenance practices under the lowland conditions in Indonesia towards a sustainable future development and management. Special attention has been given to underlying experiences considering the lessons learnt from field practices for effective utilization of lowland development and management. Finally, the analysis also reviews the technical, institutional, organizational, and other nontechnical impacts as well as the impacts of climate change on low land development.

**KEY WORDS:** Operation and maintenance practices, Agricultural drainage, Inland lowland areas, Food crops, Soil and water management, Climate change.

# SHALLOW GROUNDWATER DRAINAGE AND ITS WATER QUALITY FROM PROTECTED FARMING IN KOREA

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## ABSTRACT

In the agricultural watershed in Korea, nutrients are discharged through various means such as soil erosion, runoff, infiltration, or drainage. Protected farming has expanded by increasing the demand for value-added agricultural products in Korea. In some agricultural areas, particularly in protected farming, due to excessive fertilization and irrigation, the nutrient excess phenomenon is becoming increasingly serious. The drainage of water and non-point source pollution (NPS) management under the protected farming method needs to be devised to manage water quality of shallow groundwater and reduce NPS pollution loads from protected farming practices. This study was conducted to investigate shallow ground water infiltration and drainage from protected farming cultivation in comparison with conventional farming practices. In the protected farming field, tomato and cucumber crop were cultivated twice a year using a drip

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irrigation system and nutrients were applied by fertigation. Irrigation, soil moisture content, shallow ground water level and flow, and weather conditions were monitored and soil water and soil on protected farming sites and shallow groundwater samples at 8 different sites on the watershed were also collected during the crop growth season to investigate water drainage and nutrient leaching characteristics in protected farming. Key NPS such as electronic conductivity (EC), total phosphorus (TP), total nitrogen (TN), and nitrate-nitrogen (NO3-N) were analyzed. The results show that NO3-N concentration and EC of soil water is high in the total soil layer, and some nutrient concentration in the sub-soil layer is higher than those in the upper soil layer. In addition, the nutrient concentrations in shallow groundwater is generally higher as compared to conventional farming. Eventhough fertilization and irrigation were applied regularly for crop production, there is a possibility of over fertilization and it may affect nutrient accumulation due to poor drainage of subsoil whereas in case switching the land use from paddy fields is to protect farming or nutrient leaching when over irrigated. In addition, in areas having high shallow groundwater level, a direct impact of excessive irrigation and fertilization increased in accordance to drainage and water flow. This results will serve as the platform not only for long-term shallow groundwater water drainage and nutrient monitoring and management under the protected farming cultivation approach but also for the derivation of guidelines on farming practices enhancement to reduce NPS loads from protected cultivation.

**KEY WORDS:** Non-point source pollution, Protected farming, Shallow groundwater, Water drainage.

# THE STUDY OF WATERMELON CROP RESPONSE UNDER SHALLOW WATER TABLE AT INITIAL GROWTH FOR DEVELOPING DRAINAGE PLANING AT TIDAL LOWLAND AGRICULTURE

Momon Sodik Imanudin [1,*], M. E Armanto [2], Robiyanto H. Susanto [3]

**ABSTRACT**

Water melon cultivation is one of the suitable alternatives applied in order to increase farmers income in tidal lowland agriculture zones. The research of crop adaptation to wet soil conditions is required so that farmers will be able to decide the best planting time based on the existing land typology conditions .. The research focuses on the determining of crop physiology response during its initial growth period within a greenhouse. The treatments consisted of water table depths at 15, 10 and 5 cm below soil surface, respectively. The observation of water table surface was carried out in the field. Analysis of crop potential based on water status condition in the root zones was conducted using secondary and primary data. The results of crop adaptation at a shallow water table depth showed that treatments of water table at depths of 10 cm and 5 cm were not signficantly different in terms of crop height with a magnitude of 12.6 cm and 12.3 cm having respectively 3 leaves. However, it had a significant effect on root length with a magnitude of 11.9 cm and 3.1 cm, respectively. The Maximum crop height of 15.2 cm and 4 leaves was found upon the treatment at 15 cm water table depth. It can be concluded that farmers are advised to plant on the basis of the water table conditions of 10 cm below the soil surface. The objective of accelerated planting is that crops do not need irrigation water at a generative phase. This condition is especially recommended for C land typology which had a high porosity and low capillary flow.

**KEY WORDS:** Tidal lowland, Watermelon, Water table, Drainage.

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# IMPORTANT ROLE OF THERMAL REMOTE SENSING (TRS) IN IRRIGATION AND DRAINAGE PROJECTS (CASE STUDY: MINOO ISLAND)

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**ABSTRACT**

Temperature as one of the most important thermodynamic factors effect on some environmental parameters like rate of physical and chemical reactions, dissolution of minerals and evapotranspiration by soils and vegetation strongly. In design of irrigation and drainage systems, estimation of water requirement for cultivation of crops based on cultivation pattern, in order to avoid of water logging, water shortage and excessive consumption of water and produce run-off more than capacity of drainage system is essential, therefore accurate estimation of evapotranspiration is necessary, especially in arid and semiarid climate like Khuzestan province to manage water resources intelligently. As usual in irrigation and drainage projects, temperature data recorded by meteorological stations

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is used to estimate evapotranspiration by Penman-Monteith equation, these stations recorded temperature as spot in a small spatial scale and land cover variety does not consider in large spatial scale. Exactly because that, engineers and designers should be careful in using of data obtained by meteorological stations in big scale especially when distance between meteorological stations is away. One of the most effective and newest tools to investigation about land surface temperature (LST) is thermal remote sensing, this technology is related to remote sensing science that process and interpret data obtained in the thermal infrared region of the electromagnetic spectrum is used and can be applied as an alternative or at least complementary selection. This study is done aimed to mapping and classification of land surface temperature pattern in lands scope of Minoo Island. In order to evaluation of land surface temperature in Minoo Island, Landsat satellite images (OLI sensor) was used. We compared two recent thermal images acquired in 07/11/2015 and 07/13/2016 before and after logging operation respectively to show dynamic of temperature pattern in spatial and temporal scales. Results of this research demonstrated there was an important different between these two patterns before and after logging operation, as different period of time, pattern of LST changed with regards to land use too, in other words we observed for same places before and after logging operation (variability of time) and according to land use (variability of location) a difference between 8 to 10 Co. These results show importance of spatial and temporal changes of temperature and its role to effect on water requirement, especially in Iran plateau. Finally, authors recommend strongly application of TRS technology as an alternative for or at least a complementary method beside of traditional methods to estimation evapotranspiration by databases like NETWAT that is based on meteorological stations data provided as spot small scale.

**KEYWORDS:** TRS, Irrigation, Drainage, Water Management, Temperature.

# CLIMATE CHANGE RESILIENT WATER MANAGEMENT MEASURES IN AGRICULTURE IN FINLAND

Elsi Kauppinen [1,*], Markku Puustinen [2]

**ABSTRACT**

In Finland only about 15% of agricultural fields can be cultivated without drainage. About 58% of field areas have subsurface drains and 27% have ditch drains. The distance between the point of discharge of field drainage and the closest body of water is on average 2.3 km (median 1 km). Presently the drainage systems are utilized only in rare cases for wetlands and other elements to reduce nutrient flux and for balancing water flow.

In Nordic regions climate change will deteriorate in winter time weather conditions: snow cover has had a greatly reduced duration, and most of the precipitation is rain instead of snow. This has had repercussions for agriculture and drainage and their environmental impacts. Previously snow cover protected agricultural fields during winter from erosion and nutrient leakage. It has been already observed that agricultural fields have become more prone to erosion and consequently unprecedentedly high nutrient concentrations have been recorded in rivers downstream from agricultural areas after heavy rains and during a time when the fields have a small amount of vegetation cover. In addition the changes in the time and amount of precipitation has resulted into a need to change recommendations for the dimensioning of drainage systems.

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Sustainable practices in drainage such as two-stage drainage channels, constructed in wetlands, sedimentation ponds and floodplains should become the standard practice in Finland in order to control the eutrophication problems caused by agricultural drainage. In order to reach this goal several social and political problems should be resolved. For example there is a need to reserve larger land areas for drainage. This is especially problematic when considering the EU's Common Agricultural Policies, which include agricultural subsidies paid to farmers per cultivated hectare – the farmers see it as being especially problematical if they have to give up farming area. Despite the social and political problems two-stage drainage channels have been implemented in few cases in Finland. Several good examples of the usage of wetlands, submerged dams and floodplains also exist. The paper reviews some of the examples and presents the environmental benefits of the solutions.

**KEY WORDS:** Two-stage drainage, Sustainable agriculture, Climate change, Finland.

# WATER SUPPLY SYSTEM AND THE SUSTAINABILITY OF SMALLHOLDER IRRIGATION IN ZIMBABWE

Solomon Mutambara [1,*], Michael B. K. Darkoh [2]
Julius R. Atlhopheng [3]

**ABSTRACT**

Irrigation agriculture is critical in enhancing food security especially in Africa where the carrying capacities for most rain-fed agricultural systems have been surpassed. As a result, small shareholder irrigation schemes have been prioritized as a rural development model and have regained renewed attention from global and regional developmental bodies as a climate change adaptation measure. However, there is hardly any case of a successful small shareholder irrigation scheme in Africa as the majority of them have been unreliable and contributed very little to the host countries and the livelihoods of the farmers. The factors leading to the unsustainability of the irrigation scheme are not fully understood. The major objective of the study is to assess the impact of water supply in the sustainability of small shareholder irrigation schemes in the study area. The study targeted 8 irrigation schemes in Zimbabwe. A mixed research method was used and 316 randomly selected farmers were interviewed. Focus group discussion, key informant interviews and field observations were used to allow for the triangulation of information.

Unprecedented siltation of water bodies compounded with inequitable water sharing and poor catchment management was has threatened

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the sustainability of smallholder irrigation schemes yet interventions in the schemes did not prioritize the sand abstraction water pumping system. The Zimbabwe National Water Authority (ZINWA) as the water governing body proved to be inefficient and detached from the farmers. Farmers could not understand why they were compelled to pay for the water as 70% of them rated its service as poor. A combination of farmers' low productivity levels, debilitating dependency syndrome, ZINWA's poor service culture and political interference in water governance has affected farmers' ability and willingness to contribute towards water bills. There was poor in- field water management and some schemes were poorly designed as there was no consultation with the local people on the designing of the pumping systems. The majority of the schemes faced frequent pump breakdowns and farmers had no reserved funds for repairs and replacement investment.

**KEY WORDS:** Smallholder irrigation scheme, siltation, Water management, Replacement investment.

# MANAGEMENT PRACTICES USING OF AGRICULTURAL DRAINAGE WATER WITH DRIP IRRIGATION FOR CROP PRODUCTION AND LANDS SUSTAINABILITY IN ARID AND SEMI-ARID AREAS

Ali Heydar Nasrollahi [1,*], Saeed Boroomand Nasab [2]
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## ABSTRACT

In addition to lack of water, other elements such as high temperature, severe salinity of soil and water quality create problems in arid and semi-arid areas. Nowadays restricted water resources having acceptable quality has resulted into the reuse of low quality water such as agricultural drainage water in these areas. The use of drainage water and saline water in agriculture requires different management practices on the farm, such as increasing the efficiency of water use, leaching and soil desalinization, in addition to proper drainage and other conventional methods. High efficiency Irrigation methods with such as drip irrigation are suitable solutions for the optimal use of these resources. This study was carried out to investigate the effects of drip irrigation management strategies using saline water on corn crop in the research farm of the Water Science Engineering faculty at Ahwaz, Shahid Chamran University. The experiment was performed on split plots based on a randomized complete block design. In this research the effects of three irrigation management options; that is mixing (M1), one-alternate mixing (M2) and half-alternate mixing(M3) of three levels of saline water (S2, S3 and S4) with the Karun river water (S1), and the reviewing of its effects on yield, irrigation

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water productivity of corn and soil salinity was investigated. Irrigation management strategies and salinity were the main factor and sub-factors. Salinity levels of S2, S3, and S4 were 4, 6 and 8 dS/m respectively. Results showed that the effects of management and salinity and their interaction on yield and water productivity were significant at levels of 5 percent. The application of the half-alternate (M3) method improved yield indexes, water productivity and the leaching of soil surface layers. The Model coefficients of yield- salinity were calculated under different management scenarios of drip irrigation. The yield reduction per unit increase in soil salinity in the plant root zone the mixing, one-alternate and half-alternate management strategies were calculated respectively as being at 9.86, 12.3 and 7.14 percent. The results of this research show that drip irrigation when applied with proper management is a safe method to reuse large amounts of drainages water volumes in arid and semi-arid regions.

**KEY WORDS:** Water quality, Drainage water, Water reuse, Drip irrigation.

# FLUCTUATING WATER TABLE QUANTIFICATION USING SATURATED EXCESS WATER CONCEPT (SEW-20 AND SEW-40) AT THE RECLAIMED LOWLANDS OF INDONESIA

Ngudiantoro [1,*], Robiyanto H. Susanto [2], Iwan Nusyirwan [3]

**ABSTRACT**

Water table within the farm, at the reclaimed lowlands of Indonesia to be used for food production, plantation and pulp wood tree, is a key indicator. The water table position is a function of topography, drainage systems, rainfall, evaporation, crops, operation and maintenance, within a given water management unit. Fluctuation of water table within the farm can be quantified using "Saturated Excess Water - SEW" concept within limit of -20 cm (SEW-20) or -40 cm (SEW-40) below the soil surface. The paper will explain the results of SEW-20 and SEW-40 during one year period covering the rainy and dry months. The value of SEW-20 during the year especially the number of days related with the paddy cropping time. The paddy will be planted if the SEW-20 is more than 120 days. On the other side, the value of SEW-40 will be related with the corn cropping pattern. Corn will be planted when the value of SEW-40 is between 80 to 100 days. The development of rooting zone of rice and corn are determined by the position of water table. The plantation crops and trees would prefer as higher as possible values of SEW-40 during the year.

**KEY WORDS:** Water table fluctuation, Saturated excess water, SEW-20, SEW-40.

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# EXPERIMENTAL PERFORMANCE EVALUATION OF THREE DRAINAGE METHODS FOR PREPARATION OF SECOND CULTIVATION IN PADDY SOILS

Amirreza Rahimi [1,*], Abdolmajid Liaghat [2], Hamed Ebrahimian [3]

**ABSTRACT**

Paddy fields have the ability of multi-cultivation as compared to other crops. Low permeability rate and long term waterlogging of paddy soils cause serious problems for non-rice crops. Therefore, the aim of this study is to evaluate three different drainage methods including: 1- surface drainage, 2- subsurface pipe drainage and 3- trench drainage (filled underground trench with high-permeable material along with drainage pipe). Experiments were implemented in a physical model capable of the simulation of 7.5 meters drain spacing. Drainage water and soil moisture at different depths and distances from the drain pipe were measured. The results showed that the drainage of water via trench drainage was far more than other methods; nonetheless, the performance of trench drainage in the reduction of soil moisture was better. The required time for the top soil to reach its lower plastic limit in the subsurface, trench and surface drainage systems were obtained 26, 22 and 16 hours from the start of the experiments and 14, 11, and 15 hours after the depletion of excess water

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over the soil surface, respectively. Although surface drainage represents in faster depletion of excess water; eventually, the trench drainage proved to be the most effective alternative to provide appropriate qualifications for second-cultivation operations.

**KEY WORDS:** Physical model, Hardpan, Trench drainage, Soil moisture.

# PROPOSALS TO DIRECT AGRICULTURAL DRAINAGE WATER MANAGEMENT IN THE KHUZESTAN PROVINCE (KARUN-DEZ RIVER AREA) INTO A SUSTAINABLE AND INTEGRATIVE DIRECTION FOR PRESENT AND FUTURE SCENARIOS

Frank Riesbeck [1,*], Simon Dupree [1], Md Zillur Rahman [1]
Hamid Reza Kkodabakhshi [2], Arash Mahjoubi [2]

## ABSTRACT

Khuzestan, a south-western province of Iran, is the main region of subsurface drainage in the area. Current drainage water management faces major challenges. In particular, high volumes of saline drainage effluent lead to far-reaching environmental, social, economic and political complications. This paper attempts to evaluate possible ways to overcome current inefficiencies. A focus will be put on solutions to achieve a sustainable integrative drainage management approach (IDWM) that focusses on agriculture as the main water consumer within Khuzestan. It integrates water re-use, drainage discharge possibilities, waste water treatment (desalination) and ways to increase water use efficiencies related to irrigation and leaching. All strategies aim to improve the current situation but also to redirect Khuzestan´s drainage water management into a sustainable manner within future scenarios. The ambition is to manage present and future drainage water flows but also future irrigation water supply by establishing monitoring, controlling and modelling structures affecting both water quality and quantity. Moreover, the relation between shallow and saline groundwater within agricultural irrigation and drainage systems plays a key role within agricultural drainage water management and will be examined in detail.

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The paper is based on collected data and factors of an ongoing empirical research project jointly with Humboldt University Berlin and Khuzestan Water and Power Authority (KWPA).

**KEY WORDS:** Drainage Water Quality, Integrated Drainage Water Management, Irrigation Control Systems, Methods of Irrigation and Drainage, Monitoring of Quality and Quantity Pollution, Salinity, Treatment Technologies, Water Reuse, Khuzestan, Iran.

# A CONCEPTUAL FRAMEWORK OF KHUZESTAN INTEGRATED WATER RESOURCE MANAGEMENT (KIWRM) FOR THE BEST OF SUSTAINABLE AGRICULTURAL AND SOCIO-ECONOMIC DEVELOPMENT (CASE OF KHUZESTAN PROVINCE, IRAN)

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## ABSTRACT

The main objective of this paper is to present a conceptual framework (model) of holistic integrated management approach for improving the water use efficiency and agricultural development in Khuzestan, a south-western province of Iran. Given the observable impacts of rapid economic development in Khuzestan and climate change-based extreme conditions (in arid and semi-arid regions), there is a significant demand for a new strategy for sustainable soil/water resource management, agricultural and socio-economic development in Khuzestan. To address these needs a holistic management approach has been designed in this paper, which is based on contemporary literature review from the local and from examples of global contexts as well as collected data and factors of an ongoing empirical research project jointly with Humboldt University in Berlin and Khuzestan Water and Power Authority (KWPA). The main focus of the model is to emphasize the need of multiple approaches and inclusion of all relevant aspects (e.g. social, economic, environmental, policy, agri-crop pattern and technological), which affect the sustainable agricultural development in the province.

The framework is divided into four sub-models to cover broader aspects of agricultural development such as 1) Integrated River Water Management (IRWM), 2) Integrated Irrigation and Drainage System Management

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(IIDSM), 3) Integrated Drainage Wastewater Management (IDWM) and 4) Integrated Aquaculture and Fish Firm Management (IAFFM). The KIWRM model presented in this paper, is getting implemented through Pilot and Demonstration Projects (PDPs) on several 'Irrigation and Drainage Networks' KWPA. It is to emphasise that one way solutions for agricultural management hardly exist. Instead different strategies, timely adjusted and integrated into one system, are needed for sustainable management and to control the quality and quantity of water stabilizing Khuzestan´s agricultural and socio-economic development. Finally, an example of sub-model IDWM in Karun-Dez River area is presented in a separate paper to demonstrate how this sub-model is an integrated part of the complete (holistic management framework) sustainable water management in the province.

**KEY WORDS:** Conceptual framework, Holistic Modelling, Integrated Water Resource Management, Social, Economic, Environmental, Policy, Agri-crop Pattern and Technological Aspect, River, Wastewater, Fish Farm, Irrigation and Drainage, Khuzestan, Iran.

# DRAINAGE WATER MANAGEMENT PLAN OF THE SOUTH WEST KHUZESTAN, IRAN

Majid Sharifipour [1,*], Mahmud Hajishah [2], Arash Mahjoubi [3]
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**ABSTRACT**

The existence of four large rivers and hundred thousand flatlands have made the Khuzestan province an important agricultural area. Because of soil salinity and saline shallow groundwater, subsurface drainage is inevitable in irrigated lands of the south of Khuzestan. Drainage water disposal to receiving water bodies, usually large rivers, was a common solution for drainage water problems in the 1990s. It caused major damage, especially in the downstream sectors of rivers. Due to the development of irrigation and drainage networks (IDN) after the 2000s, it was decided to manage the drainage waters of the IDNs in the southwest of Khuzestan (with an area of 340,000 hectares) as an integrated plan. Drainage water management is dependent on environmental, economic and social conditions and also on its quality and quantity (Q & Q), which are always changing. Thus, a model for predicting drainage water Q & Q in the operation period of IDNs was developed and validated using a research field of 25 hectares. The model was executed for all IDNs to predict the discharge and salinity of drainage water during the operation period. Predicted drainage water salinity of the IDNs, was used to choose between reusing or disposing of it. Drainage water salinity of IDNs will thus be reduced during the operation period;

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therefore, the managerial approach will change cin line with the extent of the salinity. The IDNs construction schedule would then be estimated in tandem with the modelled predictions, and a timetable for drainage waters salinity and discharge for each of the IDNs could be provided. In the early operating period, especially in the reclamation stage, drainage water reuse would not be possible because of its high salinity, as a result it will be disposed of in evaporation ponds or the Persian Gulf. Salinity will be reduced over time and the drainage water will be reused for salt-tolerant crop farming, desert greening or will be transferred to water bodies. By applying the said time table, the discharge of the drainage waters that is to be transferred to reusing sites or disposed of, could be calculated. The maximum discharges of reuse or disposal drainage waters during the time will be the design discharge for re-use sites, pump stations, main transforming drains etc. Some on farm methods have also been considered to reduce the quantity and enhancing the quality of the drainage waters.

**KEY WORDS:** Drainage water reuse, Salinity, Irrigation and drainage network, Drainage water disposal, Evaporation pond.

# WATER MANAGEMENT AND FARMING SYSTEM TECHNOLOGIES WITHIN THE INDONESIAN RECLAIMED LOWLANDS FOR FOOD SECURITY OF THE NATION

Robiyanto H. Susanto [1,*], Adang Saf Ahmad [2], Ngudiantoro [3]
Jarot Widiatmoko [4]

**ABSTRACT**

Indonesians have been using lowlands nearby the rivers for food production for decades. Local indigenous people had developed paddy field with shallow intensive drainage systems within the tidal range. Paddy and coconut were planted. The Government of Indonesia since 1970 has been developing additional new settlement area for food production and transmigration up to 1.8 million ha mostly in Sumatera and Kalimantan islands. The total paddy field in combination of other crops within the lowlands of Indonesia so far is around 4.2 million ha. This paper will focus mainly on the reclaimed lowlands within the transmigration areas in South Sumatera, Jambi, South Kalimantan, West Kalimantan, East Kalimantan and North Kalimantan provinces. Water management consideration and farming systems technologies for paddy, corn and soy bean production have improved the yield. Rainfall, drainage, water retention and supplemental tidal irrigation are able to fulfill paddy water requirements at the farm level in November to March (first planting season of the year). Application of farming systems technologies have improved yield of paddy from 3-4 tons grain/ ha to 5-6 tons/ ha. In the second planting season of March-June, the use of ratton paddy and water melon for example will be benefited to adapt to the water regime during this

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period. In the drier months of June – September, corn is planted with the yield of 7-8 tons grain/ ha. Consideration of the water management and farming systems technologies has to be made depend on the site specific condition exits. Prospective uses of this approach has been implemented to around 500.000 ha of reclaimed lowlands within the transmigration areas in Sumatera and Kalimantan with an estimate of cost around Rp 3-4 million/ha. Knowledge transfer and empowering the local institutions have to be done simultaneously during this process.

**KEY WORDS:** Integrated lowland development, Water management, Farming system technology, Propagation development tdal lowland.

# SIMULATION STUDY ON THE PERFORMANCE OF AN IMPROVED SUBSURFACE DRAINAGE SYSTEM

Yuan Tao [1], Shaoli Wang [2,*], Di Xu [3]

**ABSTRACT**

New requirements have been put forward for agricultural drainage systems due to frequent floods and shortage of cultivated land in China. The improved subsurface drainage is a more efficient drainage system due to the laying of high permeability materials as filters above the drains based on conventional subsurface drainage whose function is limited by soil hydraulic conductivity. The HYDRUS model was used to evaluate the impacts of the filters' hydraulic conductivity, in addition to the filter width and height, drain spacing and depth on improved subsurface and drainage discharge with constant ponding depth to support the subsequent design. In addition water table depths at different distances from the drain pipe for improved and conventional subsurface drainage were simulated under initial conditions of saturated soil and no surface ponding. The results

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indicated that the improved subsurface drainage had a real-time drainage function due to the fact that the cumulative outflow had increased by about 45% more than the conventional subsurface drainage within 12h after the beginning of the draining of the field soil. Improved subsurface drainage lowered the water table to an appropriate depth faster than conventional ones and provided a more favourable soil moisture condition for crop growth. Furthermore, through daily water balance analysis of improved and conventional subsurface drainage with different rainfalls and initial water table depths, the results showed that subsurface drainage could reduce surface runoff effectively, especially for improved subsurface drainage. Suitable drain ability of improved subsurface drainage was beneficial in the decreasing of the amount of soil water storage after rainfall and helped to shorten subsequent draining time during water table drawdown. The research results provide a scientific basis for improved subsurface drainage design and lay a good foundation for its application. Meanwhile, it would be beneficial to enrich agricultural drainage technologies and promote the development of agricultural drainage in China.

**KEY WORDS:** HYDRUS, Improved subsurface drainage, Conventional subsurface drainage, Discharge, Water table, Runoff reduction.

# THE EFFECT OF CANAL WATER RETENTION ON THE FLUCTUATING WATER TABLE AT THE RECLAIMED LOWLANDS FARM AT TANJUNG LAGO, BANYUASIN, SOUTH SUMATERA

Warsito [1,*], Robiyanto H. Susanto [2], Edward Saleh [3], Novia Sumardi [4]

**ABSTRACT**

The reclaimed lowlands of Indonesia, respective of one 16 ha tertiary block within a 256 ha secondary block consisting of 16 tertiary blocks, are used for food production. The Paddy is planted during the rainy season of November to February followed by water melon cultivation in March to May, and corn in June to September. The fluctuation of the water table in the farm is very crusial in determining the cropping calender. Water management applying a free drainage approach is influenced by tidal water movement into the tertiary canals bordering the farmers fields. A constant water retention -10 cm below the canal bank increased the water table in the farm from -10 cm to +20 cm. Water retention (controlled drainage) mode was applied by farmers especially during the rice growing period. The release of water in the canal to a depth of -50 cm below the canal bank lowered the water table level to -20 cm. Over the 200 day experiment, soil and water samples are taken 16 times to be analyzed in relation to the fluctuating water table. The NO3-, NH4+, pH content of the water sample corresponded to the the fluctuating water table. Preliminary research results related to the water table fluctuation are discussed in this paper.

KEY WORDS: Water table fluctuation, Drainage, Reclaimded tidal lowland, Controlled drainage.

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# 6

# Topic 6:
# Drainage
# Special Issues

# THE EFFECT OF LONG TERM TIDAL IRRIGATION AND DRAINAGE ON FORMATION OF IMPERMEABLE LAYER (CASE STUDY: ABADAN ISLAND, KHUZESTAN, IRAN)

Shahram Ashrafi [1,*], Fouad Tajik [2], Mojtaba Akram [3]

**ABSTRACT**

Abadan palm date plantations have long been irrigated under tidal effects. Rivers flowing down to the sea have been and still are the water source for irrigation. During high tides, river water flows into the ditches and make subsurface irrigation possible while during low tides ditches act as the drains and water discharges out of the plant root-zone. Recently parts of the plantation has gone under traditional drainage due to rising of river water salinity and surprisingly failed to work efficiently. In order to find the cause, hydraulic conductivity of soil layers were measured using parallel ditch drains. Saturated hydraulic conductivity of the top soil (up to depth 95 cm) shows that, soil is very permeable up to 70 cm depth, but from the depth of 70 cm to 95 cm below the soil surface, it is impermeable. Piezometric measurements also have shown impermeability of the subsoil as well. Based on the piezometric measurements, soil layer located between depths of 70 to 130 cm is impermeable. Soil profile study showed three distinguishable layers in the experimental field. Although soil texture in the first layer (up to 75 cm depth) have been classified as a clayey texture, biological activities, mostly live and thick roots holes have changed the magnitude and athe size of the pores in this texture. Value of saturated hydraulic conductivity of the top soil varies from 34 m/day at

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the top soil to a very low conductivity at the depth of around 70 cm. It was concluded that in tidal subsurface irrigation, only the upper part of the soil which has been under the root spread can be assumed permeable and deep drains laid below cannot work properly.

**KEY WORDS:** Date plantation, Drain ditch, Hydraulic conductivity, Piezometer, Recharge ditch.

# A NEW DRAIN PIPE-ENVELOPE CONCEPT FOR SUBSURFACE DRAINAGE SYSTEMS IN IRRIGATED AGRICULTURE

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**ABSTRACT**

In irrigated lands, drain pipes are equipped with envelopes to safeguard the subsurface drainage system against the three main hazards of poor drain-line performance: high flow resistance in the vicinity of the drain, siltation, and root growth inside the pipe. A wide variety of materials are used as envelopes, ranging from mineral and synthetic materials to mineral fibres. The challenge is to match the envelope specifications with the soil type. As soils are rather variable, the design of envelopes is not straightforward as illustrated by the numerous norms and criteria that have been developed worldwide. These norms and criteria have been mainly developed in Western Europe and the USA and often lead to disappointing results when applied in other countries where their specifications and effectiveness have not been proven in field trials. In irrigated lands, problematical factors which are evident are that as compared to rainfed agriculture, the hydraulic function of an envelope is less important than the filter function moreover, the root growth inside the drain pipe is a major problem. To tackle these problems, an innovative envelope design

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concept, based on optimizing the geometry of the pipe and the envelope, has been tested in a 50 ha pilot area in Haran Province, Turkey. The new concept, Hydroluis®, consists of a corrugated inner pipe with two rows of perforations at the top and an unperforated outer pipe that covers about 2/3 of the inner pipe leaving the bottom part of the inner pipe in contact with the soil. The main advantage of the new concept is that it is less dependent on the soil type than the existing envelope materials. The new concept was tested and compared with a geotextile, a sand-gravel envelope and a control with no envelope material. All three envelope types had a lower sediment load as compared to the control and the sand-gravel and Hydroluis® envelopes had a considerable lower entrance resistance as compared to the geo-textile, which showed the best drain performance and showed no signs of root growth. It can be concluded that the Hydroluis® envelope is a good alternative for a sand/gravel or synthetic envelope in irrigated lands.

**KEY WORDS:** Subsurface drainage, Envelope materials, Entrance resistance, Drain performance.

# CLOSED DRAINAGE ON HEAVY SOIL: THEORY AND PRACTICE IN RUSSIA

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**ABSTRACT**

Maintaining, rehabilitation, and rational use of fertile agricultural lands are still urgent problems at present. High-quality improvement of agricultural land areas and natural agrolandscapes on the basis of multipurpose land reclamation is one of the quidelines of the activities of the Ministry of Agriculture, water management, designing and research organizations. One of the most important and effective methods of preventing lands from over wetting and bogging is closed drainage. Currently, there are 9.3 million ha of reclaimed lands in the Russian Federation, of which 4.8 million ha are drained; the balance cost of systems of all the forms of ownership totals 307 billion roubles. Out of the total area of drained lands 3.0 million ha, or 62 %, are represented with closed drainage systems, including 2.6 million ha in 29 subjects of the Russian Federation located within the Nonchernozem Zone, the remaining land areas are located in the regions of Siberia and Far East. The goal-oriented federal target program «Development of agricultural land reclamation of Russia for the period until 2020» was aimed at developing the system of rational agro-ameliorative practices for long-term operation of reclamation systems, in particular on heavy soils with the use of drainage and rehabilitation of the humid zone soils polluted as a result of human activities. This problem was successfully solved. The assessment of theoretical findings, experimental works and results of their practical use were carried out in some land reclamation project areas of the Nonchernozem Zone.

**KEY WORDS:** Close drainage, Land reclamation, wetland, heavy soil, adaptive landscape tillage.

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# DRAINAGE SYSTEM DESIGN FOR COASTAL POWER PLANT: OPTIMIZATION OF LIMITED RESOURCES

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**ABSTRACT**

The southern part of Thailand plays an important role in tourism and economic development; thus, growth in electricity demand increases steadily. To ensure stability of supply, it was decided that a base load power plant is to be developed to provide reliable and dependable electricity supply. Thepa Coal-fired Power Plant is located near the coastal area at Pak Bang Sub-district, Thepa District, Songkhla Province, Thailand. The project has an area of around 4.736 km2. The Thepa Power Plant Project covers the construction of the power plant complex, bearth and jetty facilities, as well as the construction of high voltage 500 kV transmission line.

Geographically, the Thepa District deals with both floods and droughts every year. The Office of Disaster Prevention and Mitigation proposes a plan to prevent flood and drought in the area to reduce the impact of such events on residents and the local agricultural sector. The change in land use is one factor that increases flood risk by reducing water permeability and increasing water surface runoff. To minimize the environmental impacts of developed land area, Sustainable Urban Drainage System (SUDS) techniques have been used as a tool for integrated water resources

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and water management. SUDS techniques are internationally adopted as an effective tool for sustainable design philosophies aiming not only to protect natural resources, but also to maintain good public health. In addition, the SUDS technique also preserves biological diversity by minimizing environment impact from developed land area over the long term.

This study focuses primarily on the sustainable and environmental-friendly design of drainage system for the new coastal power plant. The drainage system has been design using the Storm and Sanitary Analysis (SSA) two dimensional mathematical model which is for hydrology and hydraulics in a project. The study quantifies the criteria of the drainage system of the Power Plant. After identifying a suitable area for constructing a power plant, hydrological data including flood area, temperature, rainfall, runoff, soil properties and geometry were collected to be used as the basis for drainage design preventing flood area problems. One of the key principals in the design is to try to avoid any conflicts with the local community. After examining all relevant aspects, the criteria of drainage design and the criteria of sustainability design are set up to fully utilize available resources, not only for drainage, but also for power plant usage during construction as well as operation.

Flood prevention of the power plant is mandatory for reliable plant operation. Accordingly, the flow velocity should be designed for self-cleaning velocity. The velocity is then defined as the rate between 0.6 to 3.0 m/s to prevent sedimentation and to prevent erosion of pipe, gutter and channel. The maximum flow velocity is then quantified by the return period of rainfall at the project area. The drainage system planning is considered based on (i) Rational Method, (ii) Time of Concentrate (TOC), and (iii) Flood Routing.

The results of the study through the application of SUDS techniques show that the drainage system is composed of a 5.00 x 3.65 m 1.50 km main drain channel ., 2 retention ponds of total capacity 6,900,000 m3, and a run-off canal. This system will effectively utilize the surface runoff while providing a reliable flood prevention system to the power plant.

**KEY WORDS:** Drainage design, Power plant, SUDS, SSA, Storm Drainage, Sustain Urban Drainage System.

# MODELING STORM WATER MANAGEMENT FOR WATER SENSITIVE URBAN DESIGN USING SUSTAIN

Sattar Chavoshi [1,*], David Pezzaniti [2], Baden Myers [3]
Ashok K. Sharma [4]

**ABSTRACT**

In an attempt to transit South Australia to a water sensitive State, a plan named Water for Good was launched in 2012 which is a guide for urban and regional development of South Australia. One of the main objectives of this plan is to reduce the negative impact of urbanization on the water cycle of the cities. In order to reduce the hydrological impact of urbanization, best management practices have been proposed. Determining the topology of such structures (number, size and placement) is the key element of any urban storm water management plans. Several models have been proposed which are based on hydrologic, hydraulic or combination of both properties of the catchments. This paper addresses some of the most important models and then introduces SUSTAIN as

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a suitable model for the optimization of best management practices in South Australia. The selection of the appropriate model was based on the desired condition of the study. In order to study the potential of SUSTAIN for storm water management, a part of the Paddocks area located in Para hills, South Australia was selected which is 15.95 acres in size and was broken into five sub- catchments. The hydrologic parameters of the model were derived from a calibrated model which was developed using EPA SWMM. Three types of BMPs i.e. rain garden (bioretention), rainwater tank (cistern) and detention tank (bioretention as a surrogate) were studied. After designing the study area, defining data layers, placement of BMPs, specifying routing network and the setting of parameters for each sub catchment and BMPs, SUSTAIN was run for a minimum of six months leading up to the 2 or 5 year ARI event. A total of 15 out of 50 scenarios result into an optimized solution which can be classified in three groups according to the type of used BMPs. SUSTAIN successfully produced results for preserving peak flow rate within the catchment, producing data regarding the least cost solution for the size and placement of retention or detention storages. In the retention scenario, levels of demand (or disposal) greater than 450 L/day of retained water were required to produce an optimum result for the 2 years ARI storm event, and greater than 5000 L/day flow to preserve the existing peak flow of the 5 year ARI storm event. For detention systems, an orifice 25 mm was successfully used for preserving both the 2 years ARI and 5 years ARI. However, there did not appear to be any clear pattern in the placement of retention or detention tanks, with results varying each time a successful scenario was rerun. Further optimization with multiple outcomes is recommended to produce a pattern of optimal tank arrangement.

**KEY WORDS:** Water Sensitive Urban Design, Storm Water Management, SUSTAIN, BMP.

# SUSTAINABLE URBAN DRAINAGE (SUD) AND NEW URBAN AGENDA (NUA)

Andre Dzikus [1], Pireh Otieno [2,*], Kulwant Singh [3]

**ABSTRACT**

This paper addresses the need to reduce the impact of city development of flooding on residents and in other places, and the worsening of the water quality in streams, rivers and lakes caused by the expansion of cities. The most appropriate current solutions involve Sustainable Urban Drainage Systems (SUDS) but SUDS can only be implemented where good policies, supportive stakeholder groups and partnership working exist in order that these new ideas, which cut across existing methods and practices, will be accepted; moreover it goes on to discuss how the New Urban Agenda (NUA) shall be supporting and addressing these challenges.

Sustainable Urban Drainage Systems require several changes in thinking and practice in city planning and there are many barriers to progress including the perceived costs added to the development itself, and the increased maintenance activities required, in addition to the attractiveness of big infrastructure projects to politicians ;whereas, drainage projects are very often just 'normal work'. The inertia of planning systems also tends to discourage the good new ideas involved. However, the perceived additional costs need to be set against the costs of losing habitats and fish, food and other ecosystem services which follow, and the damage to properties and the danger to people caused by flooding which frequently results from development. The barriers to more sustainable drainage are high but a whole portfolio of potential 'Green' infrastructure solutions are available to be applied to any city in the world. There are no particular problems for high cost, or high value developments since the additional costs of drainage are small and green space is normally an integral element.

However, for most urban developments where money is tight, drainage solutions on a development site are likely to be hard concrete with no financial allocation for

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maintenance. Consequently, to achieve a more widespread use of sustainable drainage principles, greater integration into Green Infrastructure is necessary, and multiple benefits need to be clear. Otherwise the total operational life costs will not be properly recognized. Major developments and redevelopments give the opportunity for the reallocation of open space to improve its use through multiple functions. Sustainable drainage has the potential to provide habitat improvements which provide places for breeding, and to provide connectivity between SUDS and natural areas, in addition to linking directly to zones of natural habitats thus providing more sustainable solutions and greener solutions to drainage problems.

The New Urban Agenda (NUA) aims at enhancing effective urban planning and management, efficiency, and transparency through e-governance, information and communications technologies assisted approaches, and geospatial information management. Further, New Urban Agenda underscores the need to promote adequate investments in accessible and sustainable infrastructure and service provision systems for water, hygiene and sanitation, sewage, solid waste management, urban drainage, reduction of air pollution, and storm water management, in order to improve health and ensure universal and equitable access to safe and affordable drinking water as well as access to adequate and equitable sanitation and hygiene for all; and end open defecation, with special attention to the needs and safety of the fairer sex and those in vulnerable situations. NUA seeks to ensure that this infrastructure is climate resilient and forms part of an integrated urban and territorial development plans, including housing and mobility, among others, and is implemented in a participatory manner, taking into account innovative, resource efficient, accessible, context specific, and culturally-sensitive sustainable solutions.

NUA also recognizes that urban centers worldwide, especially in developing countries, often have characteristics that make them and their inhabitants especially vulnerable to the adverse impacts of climate change and other natural and man-made hazards, including extreme weather events such as flooding, subsidence, storms, including dust and sand storms, heat waves, water scarcity, droughts, water and air pollution, vector borne diseases, and sea level rise that particularly affects coastal areas, delta regions, and small island developing States, among others.

NUA also commits to promote the creation and maintenance of well-connected and well-distributed networks of open, multi-purpose, safe, inclusive, accessible, green, public spaces with high quality to improve the resilience of cities to disasters and climate change, reducing flood and drought risks and heat waves, and improving food security and nutrition,in addition to physical and mental health, household and ambient air quality, noise reduction, and promoting attractive and livable cities and human settlements and urban landscapes, prioritizing the conservation of endemic species.

**KEY WORDS:** Policies and Planning Systems, Effective urban planning and management, Impacts of climate change and other natural and man-made hazards, quality public spaces to improve the resilience of cities to disasters and climate change.

# TRENCHLESS TECHNOLOGY FOR EXECUTION OF DRAINAGE SYSTEM FOR TA PROHM TEMPLE COMPLEX, SIEM REAP, CAMBODIA

R. K. Gupta [1,*], R. K. Agrawal [2]

**ABSTRACT**

Built in 1186 in Siem Reap (Cambodia) and originally known as Rajavihara (Monastery of the King), Ta Prohm was a hindu temple dedicated to the mother of Jayavarman VII. Ta Prohm is a temple of towers, closed courtyards and narrow corridors. Many of the corridors are impassable, clogged with jumbled piles of delicately carved stone blocks dislodged by the roots of long-decayed trees. Bas-reliefs on bulging walls are carpeted with lichen, moss and creeping plants, and shrubs sprout from the roofs of monumental porches. Trees, hundreds of years old, tower overhead, their leaves filtering the sunlight and casting a greenish pall over the whole scene.

The temple has deliberately been left in a state of un-repair; for the tourist to experience "the harmony between man and nature". The decay of the structure partly due to the entwining forestation and partly due to its frequent inundation by rains has resulted in deterioration of many of its walls, floors and the roof.

The whole of the Angkor heritage area had been under study and research for a long time, particularly with regard to the problem of water management and preservation of heritage and its environment. These problem were urgent and unusual mainly because of its essential characteristics of harmony between nature with man had to be retained. During the rainy season, the water level in the moat closer to the North Eastern side, is higher by about 1 m, than the level in the other moat. Also

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the rain-water accumulated within the temple complex doesn't get drained and remains standing for 3 to 4 days. The temple complex experiences standing water up to 1m and at times up to floor level within most of the structures which affects tourism during the monsoon season.

To solve the problem of water logging in the enclosures of the temple, the Archaeological Survey of India (ASI) entrusted WAPCOS Ltd., a Government of India Undertaking under the Ministry of Water Resources, River Development and Ganga Rejuvenation to prepare and execute a drainage plan. Due to the fact that the Temple complex is a world heritage site, it was a difficult task to implement the drainage system in an open form. Therefore, a Trenchless method was used to prepare an underground drainage system.

For the preparation of the Implementation plan, Ground Penetration Radar (GPR) survey was carried out in the Temple complex to determine the actual location, depth and spreading of the tree roots. The laying of pipe lines was decided to be carried out at a lower depth than that of the tree roots to avoid any damage. The findings of the GPR Survey ensured that the Drainage pipe lines could be laid below 2m depths safely without harming the Tree roots.

The execution of the drainage system started in March, 2014 and was completed in March 2015. The drainage system comprises 16 main lines, connecting sinks to chambers and chambers to the Inner Moat, laid by using Trenchless Technology. The Drainage System also envisages 8 mainlines from the Inner Moat to the Outer Moat. The complete network comprises 25 Sinks, 11 Sink cum collection chambers and 1 chamber located in Enclosures II & III.

This drainage system, a unique in its own kind, the first ever implemented at Angkor World Heritage Area and successfully completed within the scheduled time frame. During the execution Year 2014-2015 the work was inspected twice by the Experts of ICC- ANGKOR (International Coordinating Committee for the Safeguarding and Development of the Historic Site of Angkor). The experts of ICC-ANGKOR from France, Japan and Kingdom of Cambodia appreciated the technology adopted by WAPCOS and the way it has been implemented on site. The work was also visited by Higher Dignitaries of Royal Government of Cambodia and India and other prominent persons from India and has been well appreciated.

**KEY WORDS:** entwining forestation, water logging, Ground Penetration Radar (GPR), Cambodia

# APPLICATION OF HYDRUS-2D FOR PREDICTING THE INFLUENCE OF SUBSURFACE DRAINAGE ON SOIL WATER DYNAMICS IN A RAINFED-CANOLA CROPPING SYSTEM

Fatemeh Karandish [1,*], Abdullah Darzi-Naftchali [2], Jiří Šimůnek [3]

**ABSTRACT**

Although subsurface drainage systems in paddy fields provide a suitable condition for winter cropping by combatting the waterlogging and ponding problems, they may alter the natural soil water dynamics. The cost and time involved in frequent field observations pertaining to quantification of such alterations lead to the use of simulation models, which are more plausible approaches. Therefore, in this research, the HYDRUS-2D model was applied to investigate the probable effects of different subsurface drainage systems on the soil water dynamics under rainfed-canola cropping system in paddy fields. Field experiments were conducted during two rainfed-canola growing seasons at the subsurface- drained paddy fields of the Sari Agricultural Sciences and Natural Resources University, Mazandaran province, northern Iran. A drainage pilot consisting subsurface drainage with different drain depths and spacings was designed. Canola was cultivated as the second crop after rice harvest. Measurements of water table depth and drain discharge were made during the growing seasons. The performance of HYDRUS2D model during calibration and validation

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phases was evaluated using the model efficiency (EF), root mean square error (RMSE), normalized root mean square error (NRMSE), and mean bios error (MBE) measures. Based on the criteria indices (MBE=0.01-0.17 cm, RMSE=0.05-1.02 and EF=0.84-0.96 for drainage fluxes, and MBE=0.01-0.63, RMSE=0.34-5.54 and EF=0.89-0.99 for water table depths), the model was capable enough for predicting drainage fluxes as well as the other soil water balance components. The simulation results demonstrated that water table management can be an effective strategy to sustain shallow aquifers in the subsurface- drained paddy fields during winter cropping.

**KEY WORDS:** HYDRUS-2D, Drainage flux, Dynamic simulation, Paddy field, Water table.

# EVALUATION AND COMPARISON OF LOCALLY MANUFACTURED PP450 SYNTHETIC ENVELOPES FOR COMPLEX CLAY SOILS OF NORTH AND SOUTH KHUZESTAN (IRAN)

Heydar Ali Kashkuli [1,*], Mina Afshari [2], Narges Zohrabi [3]

**ABSTRACT**

The performance of subsurface drainage pipes installed utilizing granular envelopes for 100000 ha of sugarcane/irrigation-related projects in Khuzestan has been satisfactory. However due to rising transportation and installation costs for granular envelopes requiring a wider trench, a great tendency for the use of synthetic envelopes has developed in recent years. More than 300000 ha of new irrigation projects are planned to install only locally manufactured synthetic envelopes. The complexity of soil horizons in the vast Khuzestan plain, weakness of synthetic envelope manufacturing standard enforcement laws, lack of experience, insufficient field and laboratory research are the main reasons of concern about the successful long term performance of these envelopes. In this laboratory research three different PP450 synthetic envelopes (types 1, 2 and 3) were tested on two representative soil samples obtained from North and South Khuzestan in an upward directed flow permeameter. Outflow rates from drains with increasing total head at various time intervals, gradient ratio tests as well as hydraulic conductivity of soil-envelope tests were conducted. Analysis of the results revealed that while envelope type 1 was suitable for the soil from the north (Dehkhoda project) and envelope type 3 was suitable for the soil from the south (Ramshir project).

**KEY WORDS:** Gradient ratio, Hydraulic conductivity, Permeameter, Variations of discharge.

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# INVESTIGATION THE METHODS TO ASSESS OF IMPERMEABLE LAYER DEPTH IN THE TIDAL LANDS OF MINUSHAHR

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**ABSTRACT**

The depth of the impermeable layer or the barrier in soil is one of the most important parameters in the designing of subsurface drainage systems; however the assessment of the layer is not always easy. In practice, a soil layer is considered as being impermeable or slowly permeable if its hydraulic conductivity is very small (one fifth to one tenth) as compared to the hydraulic conductivity of the upper layers. The impermeable layer is found where the soil is poorly aggregated or exhibits a massive structure. If it is permanently saturated as part of the soil profile in the lowlands and coastlands where saturation conditions prevent organism activities, soil aggregating resulting into a layer with slow permeability in the soil. The identification of the impermeable layer depth is complicated especially in regions having a variable groundwater table such as tidal regions; thus, different methods are recommended to be used for the

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accurate determination of the impermeable layer depth. The aim of the present study is the investigation and comparison of the results obtained from the main and practical methods of identification of the impermeable layer depth in the tidal lands of Minushahr in the Khuzestan province, Iran. Three sites were chosen randomly in Minushahr to test and compare the three methods of estimating the depth to the impermeable layers, i.e. soil properties in different strata, one fifth to one tenth of the weighted mean hydraulic conductivity of the upper layer and infiltration rate differences of successive layers. The results showed that the soil had a massive structure, without any roots or plant activity and organic matter in the layer of 120 to 150 cm; also, there is a change in color and mottles were observed e which in itself can be attributed to redox conditions due to the tide and fluctuation of the groundwater table; in addition there an increase in soil consistency and digging resistance in the layer of 140 to 160 cm was seen as compared to the upper layers. The results from the experiments of the saturated hydraulic conductivity indicated that the hydraulic conductivity in depths of about 150 cm is approximately one seventh of the upper layers., a ring infiltrometer test in different depths of soil also revealed a significant decrease at a depth of 150 cm as related to surface soil. The results of the present study were almost the same for soil layering, saturated hydraulic conductivity and soil infiltration rate tests in successive layers so that the impermeable layer was determined in a depth of 150 to 200 cm.

**KEY WORDS:** Impermeable Layer, Saturated Hydraulic Conductivity, Infiltration Rate.

# DETERMINING AN APPROPRIATE SYNTHETIC ENVELOPE FOR A SALINE SOIL AND EVALUATING DRAINAGE WATER QUALITY BY MEANS OF ONE DIRECTION PERMEABILITY TEST AND CYCLIC FLOW (CASE STUDY: SHADEGAN, KHUZESTAN)

Azita Ramezani [1,*], Alireza Hassanoghli [2], Seyed Majid Mirlatifi [3]

**ABSTRACT**

The selection of an appropriate envelope (filter) and management of drainage water from subsurface drainage systems play a significant role in the design and implementation of these systems. By applying synthetic envelopes instead of mineral envelopes (sand and silt), subsurface drainage systems benefit from environmental, economic and technical issues. In this research, an effort has been made to select the most proper synthetic envelope among the three prevalent PLM synthetic envelopes (Iranian PP450 and PP700 and foreign PP450) using a permeability test in accordance with ASTM D-5101 standard and the saline soil of the Shadegan drainage project (Khuzestan). In addition, salinity variations of drainage water were analyzed on the most suitable envelope through four cyclic flows (applying a flow for five days and pausing it for three days) and two hydraulic gradients (1 and 2.5). In conclusion, the average hydraulic conductivity of Iranian PP450 and PP700 and foreign PP450 respectively were measured as 0.11, 0.13, and 0.21 m/day and the average gradient ratio were equal to 0.78, 0.84, and 1.86 m/day. According to the

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permeability test, Iranian PP700 was considered as the best synthetic envelope due to lesser changes of hydraulic conductivity and gradient ratio. In the study of drainage water salinity variations which have been obtained from soil- Iranian PP700 envelope combination, the main changes of drainage water salinity, due to the soil volume limitations in the permeameter apparatus, occurred in the first 24 hours. Furthermore, drainage water salinity decreased during other days of the test. By providing more dissolution opportunity as a result of the cyclic flow, the electric conductivity of drainage water increased immediately after applying the flow.

**KEY WORDS:** Subsurface drainage, Synthetic envelope, Physical clogging, Permeameter, Drainage water, Shadegan.

# APPLICATION AND EFFICIENCY OF DIFFERENT DRAINAGE TYPES ON IRRIGATED LAND IN UKRAINE

D. Savchuk [1], O. Babitska [2,*], O. Kharlamov [3]

**ABSTRACT**

The processes of farming lands and settlement flooding are very wide spread in the south of Ukraine. These processes are accompanied with an increase in the ground water levels and thus create a lot of harmful effects. Different types of drainage systems are widely used to protect rural areas from flooding. More than 400 thousands of hectares of horizontal type drainage systems have been constructed in irrigated areas and more than 200 thousands of hectares of vertical type drainage systems have been constructed. In addition, drainage systems of different types were built.in more than 550 settlements,

During field investigations authors have estimated a high efficiency and operational reliability of gravity type horizontal drainage systems and unstable working modes of vertical type drainage systems due to its discreet working regime.

As an example, the project for a drainage system for the village of Nova Mayachka was developed taking into account experience in the design, construction and operation of drainage systems to solve the issues of flooding. In recent years this village suffered the most from flooding. The existing engineering system in the village consists of 20 wells of vertical drainage, which were made for the intake and removal of ground water, but they do not insure the removal of surface water.

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This system has recently provided a number of measures aimed at removing surface and ground water by means of the constructing of new open horizontal drainage systems, artificial ponds and closed discharges of drainage water to water lowering wells in the existing vertical drainage system. The project was developed taking into account the maximum use of the existing system of vertical drainage and the existing system of surface water removal in vicinity of the settlement.
Such drainage system construction will insure an essential increase of village security level from the harmful effects of flooding; reduce the drainage discharge and expenses for electricity to pump water out.

**KEY WORDS:** Flooding, groundwater levels, Drainage systems, Efficiency, Correlation.

# GROUNDWATER MAPPING WITH GEOSTATISTICAL METHODS: THE CASE OF MANISA SALIHLI

Yusuf Ersoyu Yildirim [1,*], İsmail Taş [2], Belgin Cakmak [3]
Murat Tekiner [4]

**ABSTRACT**

Groundwater mapping using classical methods may take months and even years based on the size of the area to be mapped. However, recently developed methods decreased the time consumed for such mapping practices to minutes. Geostatistical methods are the most commonly used methods for groundwater mapping over large areas in a short time. In the present study, groundwater levels were measured using groundwater wells opened in 9101 in a 2 ha net irrigation area under the jurisdiction of Salihli Right Bank Irrigation Association located within the boundaries of the Manisa province of Turkey (between 38° 30' – 38° 37' East Longitudes and 28° 00' – 28° 16' North latitudes of Gediz basin of Aegean region). Measurements were made in September, which is the most critical month for groundwater levels. Groundwater levels were assessed through geographical information systems (GIS) and geostatistical methods. Then, spatial distribution maps were created for groundwater levels and geostatistical methods were compared. Current findings revealed that

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groundwater levels in the North Western section of the irrigation district was closer to plant root regions and created a threat for sensitive plants in 2003. By the year 2015, groundwater levels were 150 cm or deeper. Such levels indicated efficient operations of drainage systems and high irrigation efficiency levels. Leaching and salinity monitoring were recommended for the study area.

**KEY WORDS:** Ground water, Geostatistics, Manisa Salihli.

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