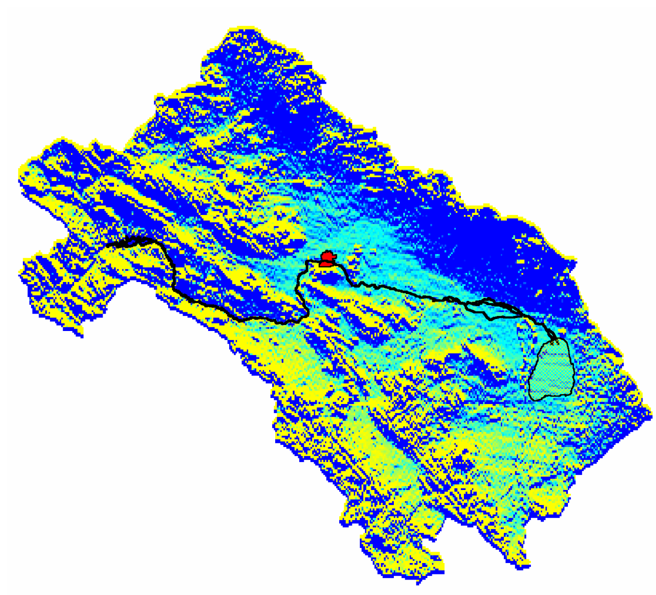
Sustainable Irrigation and Water Management in the Zayandeh Rud Basin, Iran

Proceedings of workshop on

Sustainable Irrigation and Water Management in the Zayandeh Rud Basin

Esfahan, Iran, 19-21 November 2000.



Research Report No. 6

Iranian **A**gricultural **E**ngineering **R**esearch **I**nstitute
Esfahan **A**gricultural **R**esearch **C**enter
International **W**ater **M**anagement **I**nstitute

IAERI EARC IWMI

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The IAERI-EARC-IWMI collaborative project is a multi-year program of research, training and information dissemination fully funded by the Government of the Islamic Republic of Iran that commenced in 1998. The main purpose of the project is to foster integrated approaches to managing water resources at basin, irrigation system and farm levels, and thereby contribute to promoting and sustaining agriculture in the country. The project is currently using the Zayendeh Rud basin in Esfahan province as a pilot study site. This research report series is intended as a means of sharing the results and findings of the project with a view to obtaining critical feedback and suggestions that will lead to strengthening the project outputs. Comments should be addressed to:

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Proceedings of Workshop on

Sustainable Irrigation and Water Management in the Zayandeh Rud Basin

Iranian Agricultural Engineering Research Institute
Esfahan Agricultural Research Center
International Water Management Institute

Abstract

A workshop was organized in the context of the project "Sustainable Irrigation and Water Management in the Zayandeh Rud Basin". This project is a collaborative effort between the Iranian Agricultural Engineering Research Institute, the Esfahan Agricultural Research Center and the International Water Management Institute, Sri Lanka. This report includes the abstracts and presentations of the workshop, which was held at the Esfahan Agricultural Research Center, Iran, on 19th to 21st of November 2000. The main objective of the workshop was to expose non-project project institutions and individuals to the project activities, and at the same time to get feedback and recommendations for future activities in the context of the project.

Abstracts and presentations are described in this report as well as the feedback obtained during the discussion session.

Table of contents

Sustainable Irrigation and Water Management in the Zayandeh Rud Basin

Workshop to discuss progress on the collaborative research project between the Iranian Agricultural Engineering Research Institute (IAERI) and the International Water Management Institute (IWMI).

Date: 19-21 November 2000

Venue: Esfahan Agricultural Research Center

Introduction

A collaborative project commenced between the Iranian Agricultural Engineering Research Institute, the Esfahan Agricultural Research Center and the International Water Management Institute, Sri Lanka, in 1998. The main objective is to explore ways in which integrated management of water resources at basin, irrigation system and farm level could be developed in order to promote future sustainable agricultural development.

The first phase of the project has been completed and an symposium will be held where the first preliminary results will be shared with other agencies, and the further directions of the project will be discussed.

Program

Day 1

Registration 8:30-9:00

Opening ceremony, 9:00-10:30

9:00-9:05	Program announcement *Mr. Sadatmand*
9:05-9:10	Holy Qoran recital *Mr. Kakai*
9:10-9:30	Welcome address *Dr. Damadzadeh (director Esfahan Research Center*
9:30-9:50	Welcome address and current agricultural situation of Esfahan Province *Mr. Abutalebi (director-general Agricultural Organization Esfahan Province)*
9:50-10:10	Official opening *Dr. Keshavarez (deputy-minister)*
10:10-10:30	Introduction to the project *Dr. Hammond Murray-Rust (project leader)*

Break (10:30-11:00)

Irrigation systems and basin scale hydrology and salinity (11:00-13:00)

11:00-11:30	Irrigation supply and demand for the major irrigation systems in the Zayandeh Rud. *Mr. Mamanpoush*

11:30-12:00 Water and salinity basin model applied for Zayandeh Rud. *Mr. Salemi*

12:00-12:30 Assessment of the productivity of water in Zayandeh Rud. *Dr. Peter Droogers*

Lunch and praying (12:30-14:30)

Remote sensing and Geographic Information Systems (14:30-15:30)

14:30-15:00 Long term evapotranspiration monitoring using satellite images. *Dr. Ambro Gieske*

15:00-15:30 Monitoring NDVI using satellite images. *Mr. Toomanian*

Day 2

Field scale agro-hydrology and salinity (9:00-10:00)

9:00-9:30 Soil-water-crop-salinity modeling, application for Rodasht. *Mr. Akbari*

9:30-10:00 The use of saline water for crop production. *Mr. Feizi*

Groundwater (10:00-10:30)

10:00-10:30 Groundwater-surfacewater interactions in the Lenjanat district. *Mr. Miranzadeh*

Break (10:30-11:00)

Institutional and management aspects (11:00-13:30)

11:00-11:30 Irrigation in the basin context *Mr. Torabi*

11:30-12:00 Optimizing agricultural inputs in Zayandeh Rud command area. *Mr. Solaimanypour*

12:00-12:30 Managerial aspects of irrigation. *Dr. Hammond Murray-Rust*

Lunch and praying (12:30-14:30)

Discussions (14:30-16:30)

Discussions lead by: *Dr. Hammond Murray-Rust, Mr. Torabi, Mr. Toomanian*

Day 3

Field trip (8:00-14:00)

Field trip Zayandeh Rud Basin

Field trip organized in the context of the symposium on *Sustainable Irrigation and Water Management in the Zayandeh Rud Basin*. Esfahan, Iran, 19-21 November 2000

Date: 21 November 2000

Starting point: Esfahan Agricultural Research Center

Objectives

The objectives of the field trip are to get a better understanding of:

- irrigation practices in Nekouabad Right Bank
- field experiments at Kabutar-Abad research station
- applications of Remote Sensing (RS) and Global Positioning System (GPS)

Program

8:00 Departure Esfahan Agricultural Research Center

9:00-9:30 Explanation irrigation practices at Nekouabad Right Bank diversion dam

10:00-11:00 Demonstration use of RS and GPS

11:30-13:00 Kabutar-Abad research station

14:00 Arrival Esfahan Agricultural Research Center

Introduction to the Iran-IWMI collaborative research project

H. Murray Rust

International Water Management Institute, Sri Lanka

The Iran-IWMI Collaborative Research Project was established in 1998 to undertake research to find ways to improve the productivity of water in irrigated agriculture. The project, which is fully funded by the Government of Iran, involves a collaboration between different institutes: the Agricultural Research, Extension and Education Organization of the Ministry of Agriculture, Tehran; the Iranian Agricultural Engineering Research Institute in Karaj; the Esfahan Agricultural Research Center; and the International Water Management Institute. In the initial stages the project has focussed efforts in the Zayandeh Rud Basin in Esfahan, but it will expand in 2001 to include the Salinity Research Institute which is based in Yazd.

The project looks at water management in the context of overall water availability at basin level. The traditional approach to improving agricultural productivity focuses on providing a series of inputs to farmers, including water, fertilizer, seed, credit and extension services and hopes that the outputs will be in the form of sustainable system of improved agricultural production, improved water productivity, equity of benefits.

However, when water is in short supply and salinity affects production it is necessary to look at water in the basin context. We need to know about overall water availability for agriculture at each point in the basin, the changing salinity of water and of soils as we move downstream, the amount of re-use of water and the quality of that reused water. Because each irrigation system, each sub-system and each farmer faces a different combination of water availability, water quality, soil type and cropping pattern we have to make sure the advice and information provided is relevant to the needs of each part of the basin. We also have to ensure that the activities of farmers in one part of the basin do not have a negative impact on downstream water users.

The project has five components which try to develop a more effective package of advice and information for farmers: basin water availability for agriculture, irrigation performance assessment, farm level studies to improve productivity, groundwater and salinity, and the use of remote sensing and geographic information systems to understand the variations in inputs and outputs at different parts of the basin.

Sustainable Irrigation and Water Management in the Zayandeh Rud Basin

A Collaborative Research Activity Involving

Iranian Agricultural Engineering Research Institute
Esfahan Agricultural Research Center
International Water Management Institute

IAERI EARC IWMI

International Water Management Institute (IWMI)

- One of 16 members of the Consultative Group for International Agricultural Research
- Purpose is to promote water management methods for sustainable and productive agriculture, and to help in efforts to eliminate poverty
- Based in Sri Lanka, with regional offices in Sri Lanka, Pakistan, South Africa and, in 2001, also in India and Thailand
- Originally established to improve irrigation management but has extended its mandate to look at water management in the context of river basins

IAERI EARC IWMI

Main Research Areas of IWMI

- Re-Inventing Irrigation
  - Global Assessment of Irrigation needs
  - Irrigation in the Basin Context
  - Management of Large Irrigation systems
- Water Management for Smallholder Irrigation
- Groundwater
- Water Management Institutions
- Impact on Health and the Environment

IAERI EARC IWMI

Irrigation in the Basin Context

- Throughout the world water is increasingly in scarce supply but demand is growing
- Water must be managed to meet demands from agriculture, human requirements for washing and drinking, and industrial demand
- Water management activities must be integrated to make maximum use of limited availability of water

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Our target….

… farmers of Iran

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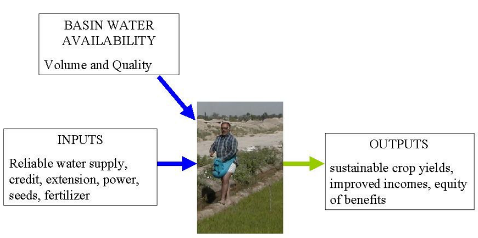

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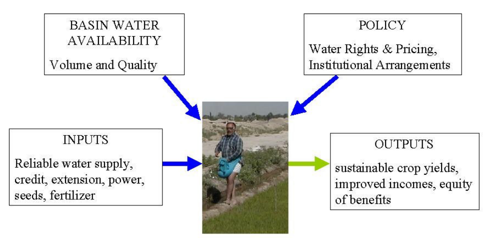

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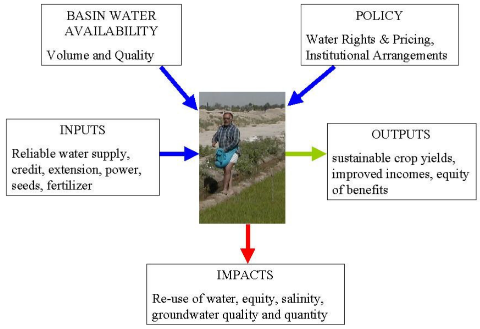
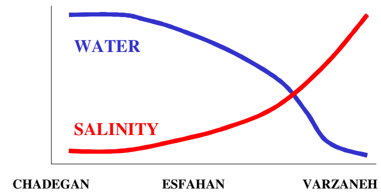


IAERI EARC IWMI

Summary of the Problem in Zayandeh Rud



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Project Activities

- Basin Level Water Resources Availability for Irrigated Agriculture
- Irrigation System Performance
- Field Level Studies of Productivity
- Groundwater and Salinity
- Remote Sensing and Geographic Information Systems

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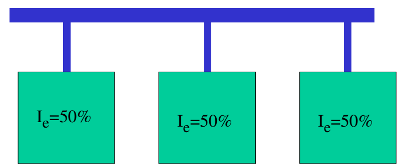
Irrigation System View of Water Use Efficiency….. Only 50%



Conclusion: Irrigation efficiency is low and must be improved

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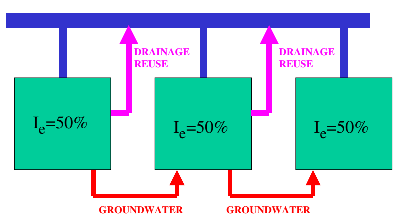
Basin view of Water Use Efficiency ………….. is now 83%



Conclusion: Basin level water utilization is very high and improving efficiency in one irrigation system will affect users in downstream systems.

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Irrigation supply and demand for the major irrigation systems in the Zayandeh Rud Basin

A.R. Mamanpoush[1], M. Akbari[1], H. Murray-Rust[2], H. Sally[2]

[1]*Esfahan Agricultural Research Center, Iran*

[2]*International Water Management Institute, Sri Lanka*

In a water-short, closed basin such as the Zayandeh Rud it is important to ensure that irrigated agriculture performs as well as possible. Valuable water cannot be allowed to go to waste, particularly when there is increasing competition for scarce water from other sectors. At irrigation system level performance can be assessed in terms of the ratio of the water consumed by evapotranspiration divided by water delivered to the head of the irrigation system. If a high percentage of delivered water is utilized by evapotranspiration, then we can deduce that there is a high level of performance. Such a performance analysis, in terms of supply and demand was undertaken for the four main irrigation systems in the Zayandeh Rud Basin.

Water supply to the systems was obtained by analyzing data provided by the Ministry of Energy on a monthly base for 1995-1996. Water demand was estimated by applying Cropwat to the dominant crops in the systems and multiplying the results with the cropping pattern in each system. However, cropping data obtained from village data appeared to be very unreliable. A combination of district data and GIS analyzes gave more reliable results and were used for the calculation of the total demand per system.

For all the systems the supply was higher than the demand for September-December, while the opposite, a deficit, occurred from January-May. The annual trend for the two Nekouabad systems indicated that there was a balance between supply and demand. For Abshar RB the annual surplus was $45 \cdot 10^6$ m^3, while Abshar LB had an annual deficit of $143 \cdot 10^6$ m^3.

It was concluded that a more accurate estimate of the cropping pattern is essential for a sound supply and demand analysis. The use of remote sensing in combination with ground thruthing is recommended. The overall conclusion was that the methodology applied in this study is an essential tool in analyzing the performance of the irrigation systems, which is the first step to recommendations for a more productive use of water.

Irrigation supply and demand for the major irrigation systems in the Zayandeh Rud Basin

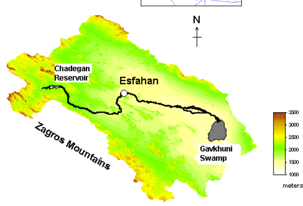
Ali Reza Mamanpoush

Outline

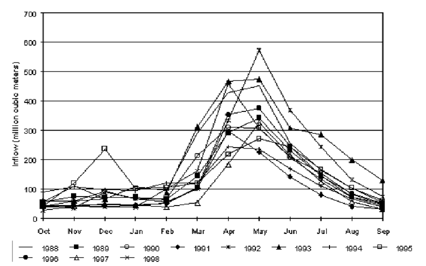
- Description of Zayandeh Rud Basin
- Irrigation systems
- Crop, cropping intensities
- Water supply
  - Releases Chadegan dam
  - Extractions of Groudwater
- Analysis of supply and demand

Description of Zayandeh Rud Basin

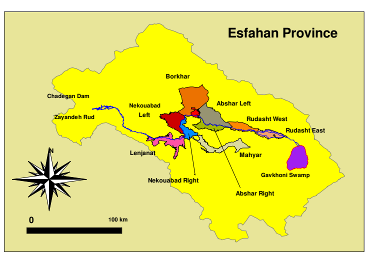
- Physical Description
- Climatic
- Precipitation



Inflow into chadegan reservoir



Layout of main irrigation

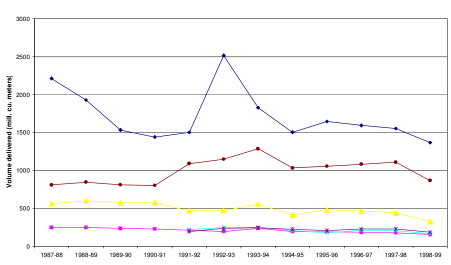


Supply and Demand

- Supply
  - Data from releases to systems (Min. of Energy)
- Demand
  - Cropped areas (ha)
  - Cropwat (mm)
  - Total demand per system
- Four systems

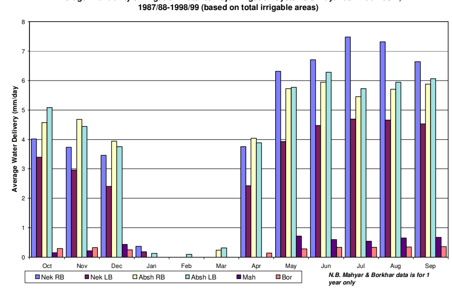
Supply

Annual Water Releases from Chadegan Reservoir and Water Issued to Major Irrigation Systems, Zayandeh Rud Basin



Water availability

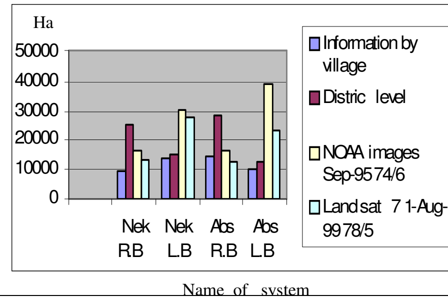
Average Availability of Irrigation Water to Major Irrigation Systems of Zayandeh Rud Basin, 1987/88-1998/99 (based on total irrigable areas)



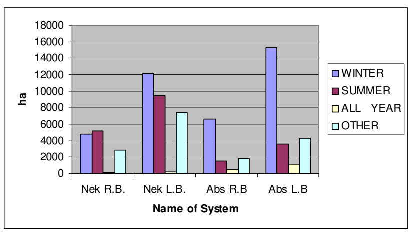
Demand

- Cropped areas
  - Village data
  - District data
  - Satellite

Irrigated areas



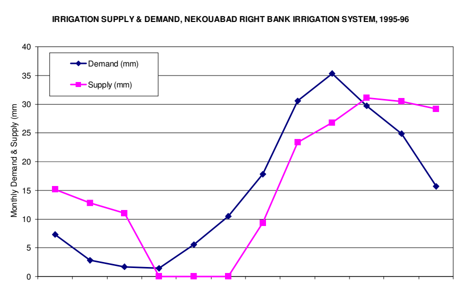
Cropped Area (ha) 74-75 (95-96)



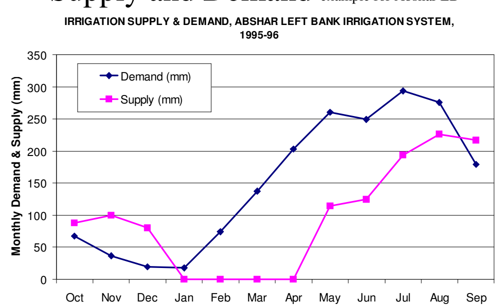
Total demand example for Nekouabad RB

Nek RB	1995-96			
Month	Area	Demand	Supply	Surplus(+)/Deficit(-)
	(ha)	(MCM)	(MCM)	(MCM)
Oct	14050	7.27	15.18	7.91
Nov	7137	2.86	12.76	9.90
Dec	7137	1.64	11.02	9.38
Jan	7137	1.45	0.00	-1.45
Feb	7137	5.52	0.00	-5.52
Mar	8206	10.47	0.00	-10.47
Apr	9831	17.76	9.37	-8.39
May	9831	30.54	23.37	-7.17
Jun	12417	35.30	26.82	-8.48
Jul	9697	29.65	31.08	1.43
Aug	8734	24.81	30.45	5.64
Sep	8734	15.72	29.13	13.41
Annual		182.99	189.18	6.19

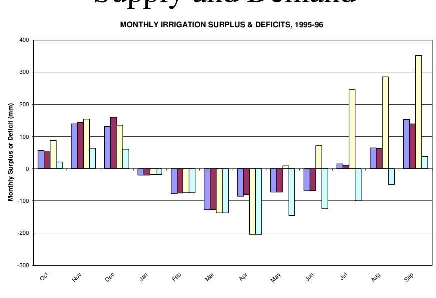
Supply and Demand example for Nekouabad RB



Supply and Demand example for Abshar LB



Supply and Demand



Discussions, future work

- Supply and Demand for 1999-2000 (dry)
- Expand cropping data
  - District data
  - Remote Sensing / GIS
- Include more climate stations in Cropwat
- Understanding conjunctive use of canal & Groundwater
- Optimize supply and demand

Exploring Basin Scale Salinity Problems Using A Simplified Water Accounting Model: The Example Of Zayandeh Rud Basin, Iran

P. Droogers[1], <u>H.R. Salemi</u>[2], A. Mamanpoush[2]

[1]*International Water Management Institute, Sri Lanka*

[2]*Esfahan Agricultural Research Center, Iran*

Water scarcity and salinization are major threats to sustainable irrigation in Iran as well as other parts of the world. Irrigation schemes are part of a basin and as such, irrigation research must be conducted in a basin context. For the Zayandeh Rud basin in central Iran, a simplified Water and Salinity Basin Model (WSBM) was developed for a quick analysis of river basin processes. First the model was calibrated and used for current and past water resources analyses. Despite the simplicity of the model, observed and simulated stream flows were similar, proving that the model could be used for scenario analyses. The first scenario was setup to analyze the effect of more efficient irrigation techniques on the basin water resources. As a consequence of these efficient irrigation practices, return flows will decrease, resulting in less water available for downstream users. It was concluded that the effect on the downstream irrigation schemes was dramatic, with a 22% decrease in yield. A second scenario was defined where the effect of an increase of water extraction for Esfahan was evaluated. In terms of basin scale water quantity aspects this increased extraction is negligible as extractions are relatively low and return flows are high. The last scenario was developed to study the additional releases required from the reservoir to provide sufficient water for expansion of the tail-end Rudasht irrigation scheme. If no restriction is imposed on water quality, additional releases from the reservoir are limited. However, if salinity levels are not to exceed 2 dS m^{-1}, mean annual water release requirements from the reservoir will increase from 52 $m^3 s^{-1}$ to 64 $m^3 s^{-1}$, and peak requirements during the irrigation season will increase from 85 to 112 $m^3 s^{-1}$. Finally, it was concluded that the methodology and the model developed were useful for a swift and transparent analysis of past, current and future water and salt resources, and to perform scenario analyses.

Water and salinity basin model applied to Zayandeh Rud

by
H.R. Salemi
IAERI

authors are grateful to Mr. Asadi, Mr. Zahabsani, and Mr Sherani from the Ministry of Energy, office Esfahan, for kindly providing some of the data used in this study

Outline

- Introduction
- Methods
- Scenarios
- Results
- Conclusions
- Future Activities

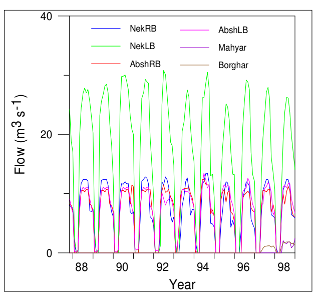
Method (I)

- Model WSBM (Water and Salinity Basin Model)
- Assumptions
- Schematic stream flow network of the Zayandeh

Method (II)

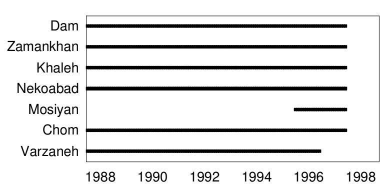
- Model WSBM (Water and Salinity Basin Model)
  - Input data

Extraction pattern for the main irrigation schemes



Data availability on extractions to run the simulation model

Data availability to verify the simulation model

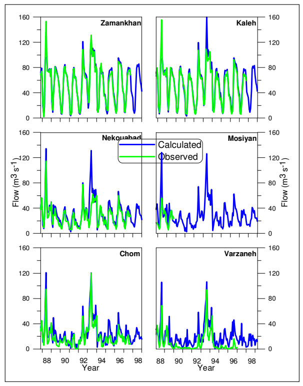


Scenarios

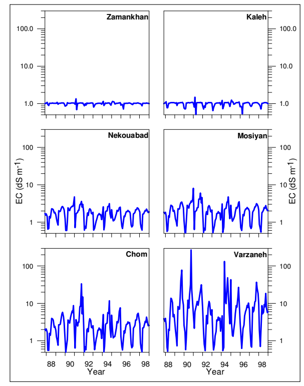
- Scenario (i)
  - Increased irrigation efficiency
- Scenario (ii)
  - Increased extractions to Esfahan
- Scenario (iii)
  - Water requirements for downstream development

Results (I)

- Model performance
  - Observed and simulated flows

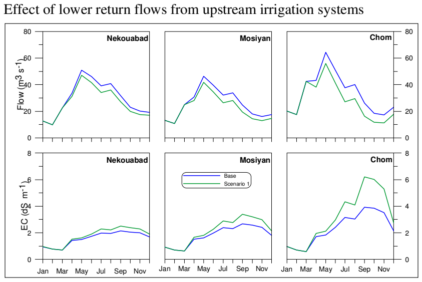


- Simulated EC values along the river

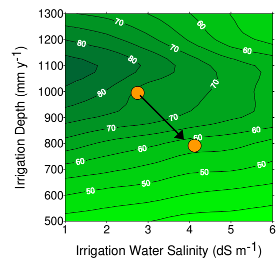


Scenario 1

- Effect of lower return flows from upstream irrigation systems



Water quantity and quality vs. yield

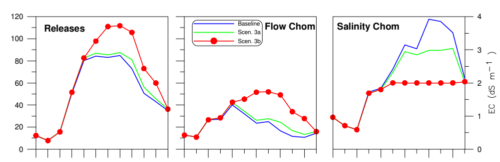


Scenario 2

- Increased supply to Esfahan town
- Effects on flows are small
  - Extractions relatively low
  - Return flows are high
- Water quality aspects

Scenario 3

- Additional Required Releases



Conclusions

- Increased efficiency will result in lower return flows having a negative impact on downstream users
- Increased supply to Esfahan has minor effect on water balance
- Development of Rudasht requires substantial increase in releases from reservoir
- Model useful tool to study scenarios

Future Activities

- Expand scenarios, drought
- Validate EC values with measured data
- Apply to other basins
- Linkage to irrigation system and field scale

Assessment of irrigation performance using NOAA satellite imagery

P. Droogers[1], **W.G.M. Bastiaanssen**[2], **A. Gieske**[2], **N. Toomanian**[3], **M. Akbari**[3]

[1]*International Water Management Institute, Sri Lanka*

[2]*ITC, International Institute for Remote Sensing and Earth Sciences, The Netherlands*

[3]*Esfahan Agricultural Research Center, Iran*

Performance of four irrigation systems in the Zayandeh Rud, Iran, was assessed for the systems as a whole, rather than on only official registered water extractions and uses. NOAA satellite images were analyzed using the SEBAL algorithm to obtain evapotranspiration, biomass production, and soil moisture contents. The missing term in the water balance was used to estimate groundwater extractions and unaccounted extraction from the river. For Abshar-Left groundwater extraction surpassed surface water applications, while for Nekouabad-Left groundwater extractions were very low. For Abshar-Right a large amount of water was pumped directly out of the river. The assessment of the systems was expressed by the Productivity of Water, defined as kg biomass over m^3 water evaporated. Productivity was higher (~0.72 kg m^{-3}) for the systems relying on surface water (Nekouabad-Left and Abshar-Right) than for the conjunctive systems, reflecting the difference in water quality between groundwater and surface water. Finally, it was concluded that the advantages of the methodology presented here over the traditional assessments are: (i) most data is readily available, (ii) all water users are included, (iii) groundwater extraction can be estimated, and (iv) a real time assessment can be set up using this approach.

Assessment of the Productivity of Water in Zayandeh Rud

Peter Droogers
IWMI

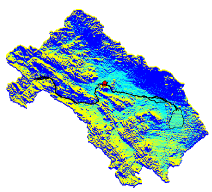
International Water Management Institute
Sri Lanka

Outline

- Capacity of Zayandeh Rud Basin
- Efficiencies, Productivity of Water
- Assessment of Irrigation Performance using Satellite Images

Capacity of Zayandeh Rud (1)

- Question:
  - How much irrigation can be applied in Zayandeh Rud Basin?
- Rough estimate
  - Annual average releases
  - Annual average crop water requirement



Capacity of Zayandeh Rud (2)

- Annual mean releases
  - Chadegan reservoir releases 1700 MCM (1988-1998)
- Annual average crop water requirement
  - 1000 mm yr^{-1}
- Zayandeh Rud capacity
  - 170,000 ha

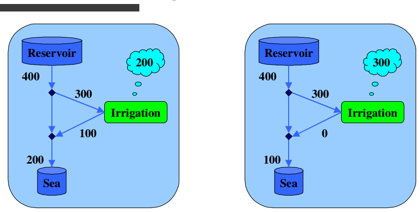
Capacity of Zayandeh Rud (3)

Name of System	Designed Command Area (ha)
Nekouabad Right Bank	13,500
Nekouabad Left Bank	48,000
Abshar Right Bank	15,000
Abshar Left Bank	15,000
Borkhar	36,000
Rudasht Left & Right	47,000
Mahyar	24,000
Total	198,500

Productivity of Water (1)

- Water short basin
- Increase irrigation efficiency (pressurized irrigation system)

Productivity of Water (2)



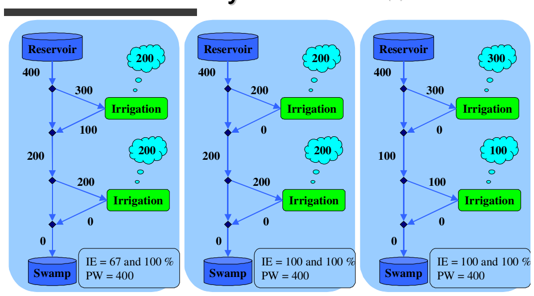
$$\text{Irrigation Efficiency} = \frac{200}{300} = 67\%$$

Productive Water = 200

$$\text{Irrigation Efficiency} = \frac{300}{300} = 100\%$$

Productive Water = 300

Productivity of Water (3)



Productivity of Water (4)

- Basin context
- Use Productivity of Water (kg m^{-3})
- Reduce soil evaporation
- Proper salt management

Assessment of irrigation performance using NOAA satellites data

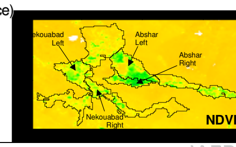
Peter Droogers, Wim Bastiaanssen, Ambro Gieske, N. Toomanian, M. Akbari

Introduction

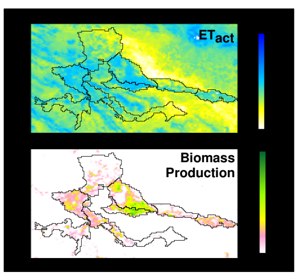
- Objective:
  - compare the performance of the main irrigation systems in Zayandeh Rud Basin
- Concept of the Productivity of Water
- Use satellite data
- Contribution of groundwater

NOAA satellites

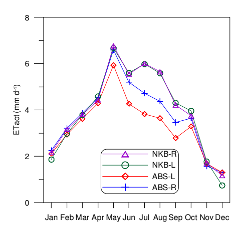
- NOAA satellites (National Oceanographic Atmospheric Agency)
  - resolution ~ 1x1 km^2
  - public domain
  - daily
  - visible and non-visible reflection
- SEBAL (Surface Energy BALance)
  - evapotranspiration
  - biomass production
- 12 months 1995

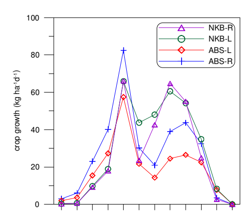


SEBAL results (April 1995)



SEBAL Results (1995)





SEBAL Results (1995)

System	ETact mm	Biomass kg ha^{-1}	PWdepl kg m^{-3}
NKB-R	1475	9388	0.64
NKB-L	1458	10528	0.72
ABS-L	1211	6806	0.56
ABS-R	1364	9894	0.73

System	ETact mm	Releases mm	Precipitation mm	Balance mm
NKB-R	1475	882	123	-471
NKB-L	1458	1227	123	-108
ABS-L	1211	439	123	-649
ABS-R	1364	891	123	-350

Conclusions

- Productivity of Water versus Efficiency
- Satellites useful tools
- Assessment first step:
  - improve systems
  - simulation modeling

Monitoring evapotranspiration, soil moistures and biomass using NOAA-14 and Landsat 7 satellite images

A. Gieske[1], W.G.M. Bastiaanssen[2], N. Toomanian[3], M. Akbari[3]

[1]*Institute for Aerospace Survey and Earth Sciences (ITC), Netherlands*

[2]*WaterWatch, Netherlands*

[3]*Esfahan Agricultural Research Center, Iran*

Actual evapotranspiration, soil moisture and biomass can be determined efficiently over large areas through the combined use of satellite images calibrated by data from one or more synoptic weather stations. In this presentation a brief overview is given of the main aspects of the method as applied in the present study of the Zayandeh Rud Basin:

- Satellites used
- Physical methods to process the image and weather data
- A description of the products: evapotranspiration, soil moisture and biomass

Images from two satellites are used in this study: NOAA-14 (LAC images) and Landsat 7 (ETM+). A time series of over 200 NOAA images is available, covering the period 1995 until July 2000. Analysis of the images is still underway and here only the 1995 results are discussed. The presentation by Toomanian will discuss the preprocessing of the NOAA images in more detail. The preliminary results obtained from an analysis of two Landsat 7 images is also presented (1-8-1999 and 2-7-2000).

The physical method to convert the acquired images into evapotranspiration, makes use of evaluation of the surface energy balance, which was developed as the SEBAL method by Bastiaanssen (1995). For the implementation of SEBAL, climatic data is required on radiation, atmospheric conditions such as temperature, windspeed and humidity: very much the same data as is required in the calculation of Penman Potential Evaporation. In this study use is made of the climatic data of the Kabutar Abad research station. The Landsat analysis concentrates on a small area in the Nekouabad district, while the NOAA analysis is extrapolated to a much larger area, ranging from Gavkhoni Swamp to Chadegan Dam.

The first results obtained with the NOAA images, relating the NDVI time series to irrigated areas, is discussed in the presentation by Toomanian. Furthermore, areal estimates can be obtained for the actual evapotranspiration, soil moisture deficit, and biomass. Some examples are given for both the Landsat and the NOAA imagery. It is planned to extend the analysis to the entire period 1995-2000. More field work on cropping patterns and more climatic data are required for better calibration of the methods used.

Determination of EVAPOTRANSPIRATION and BIOMASS by NOAA and Landsat satellites

(Zayandeh Rud Catchment, Esfahan, Iran)

Ambro Gieske[1], W. Bastiaanssen[2], N. Toomanian[3], M. Akbari[4]

November 2000

1 ITC, International Institute for Remote Sensing and Earth Sciences, The Netherlands
2 ITC, International Institute for Remote Sensing and Earth Sciences, The Netherlands
IWMI, International Water Management Institute, Sri Lanka
3 Member of the Scientific Board, Soil and Water Division, Esfahan
4 Member of the Scientific Board, Agricultural Engineering Division, Esfahan

Outline

Satellites
- NOAA/AVHRR series1995-2000
- Landsat 7 1/8/99 & 2/7/2000
- Other satellites Meteosat, SPOT, Ikonos, etc.

Methods
- Surface Energy Balance (SEBAL)
- Calibration by weather stations

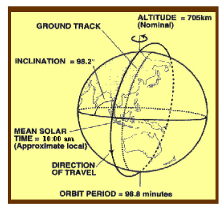
Products
- Actual evapotranspiration
- Soil moisture
- Crop growth rate
- Irrigation Performance

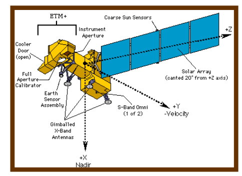
Satellites - Objectives

Use of Satellites → land use planning, geology, soil science, weather and climate, navigation, etc, etc

In this project → crop patterns, evapotranspiration, crop growth rates, irrigation performance

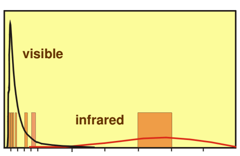
Satellites



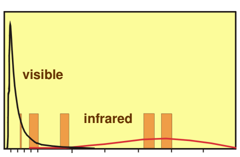


Landsat 7

Satellites - bands

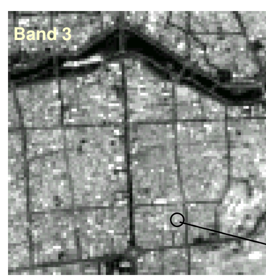


Landsat 7 ETM+
7 in visible range
1 in infrared

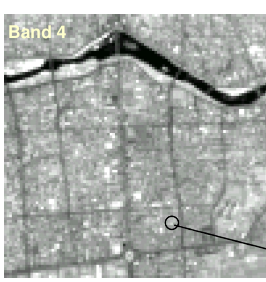


NOAA 14/AVHRR
2 in visible range
3 in infrared

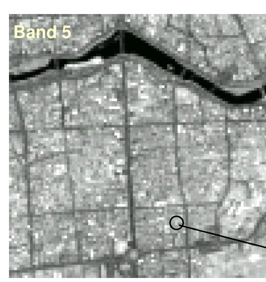
Satellites - Composite Images



Satellites - Composite Images

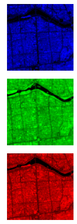


Satellites - Composite Images

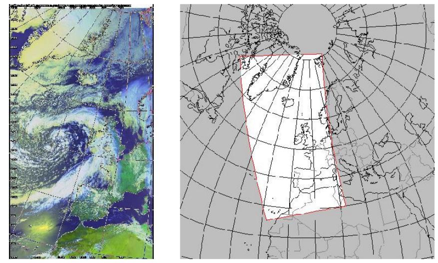


Satellites - Composite Images

Assign a color to each band and combine



Satellites - NOAA/AVHRR



2400 km scan line - 1 km pixel size

Satellites - Landsat 7 image

Date 1-8-1999
False Colour
Bands 7, 4, 3
pixel size 30m

Nekouabad
right bank

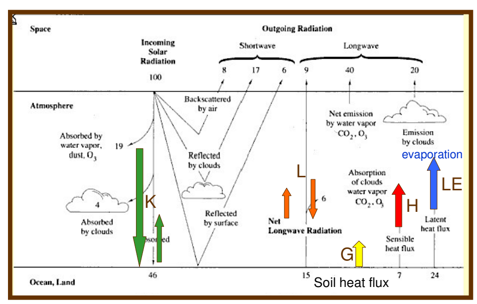
Satellites - summary

satellite	pixel size	repeat cycle	track width	typical scene	price
NOAA-14	1 km	1 day	2400 km	1000x1000 km	free
Landsat 7	30 m	16 days	185 km	185x195 km	US$600

Methods

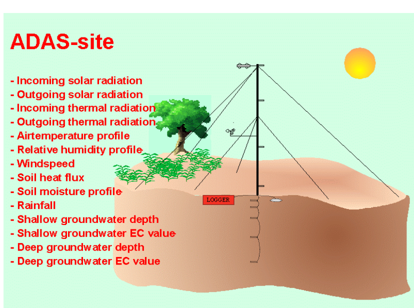
- Surface Energy Balance
- Weather Station Calibration
- Computer programs (not discussed here)

Methods - Energy Balance



Rn=t*Kexo-t*r*Kexo+Lin-Lout LE = Rn-G-H

Methods - Weather Station

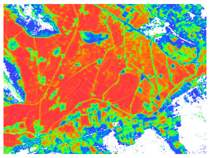


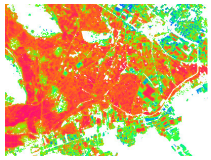
Products

- Vegetation index (NDVI) - irrigated area
- Daily evapotranspiration (E_a)
- Daily potential evapotranspiration (E_p)
- Soil moisture deficit (E_p-E_a)
- Soil moisture (%)
- Biomass growth rate (kg/ha/day)
- Irrigation performance indicators

Products - evapotranspiration

Landsat 7 ETM+





legend 1/8/99 2/7/00

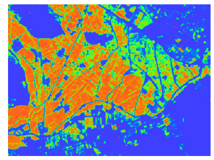
10 mm/day

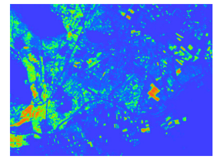
0

Preliminary results
further calibration required

Products - biomass

Landsat 7 ETM+





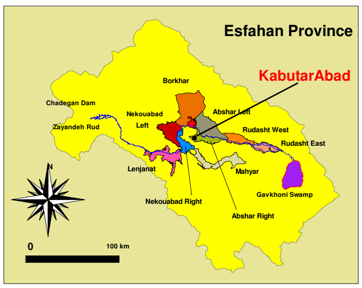
legend 1/8/99 2/7/00

400 kg/ha/day

0

Preliminary results
further calibration required

Products - Irrigation Districts



CONCLUSIONS

- Remote Sensing methods allow cheap and fast evaluation of evapotranspiration, biomass growth rates and irrigation performance on levels of basin, irrigation system and even field scale.
- It has become possible to study basin water balance components over longer periods of time, making use of satellite archives.
- Further calibration and field work is required to adjust the Energy Balance Methods more precisely to the Esfahan environment.

Monitoring NDVI of the main irrigation systems in the Zayandeh Rud Basin with NOAA/AVHRR during 1995

N. Toomanian[1], M. Akbari[1], A. Gieske[2]

[1]*Esfahan Agricultural Research Center, Iran*

[2]*Institute for Aerospace Survey and Earth Sciences (ITC), Netherlands*

The processing and analysis is discussed of a set of 40 NOAA-14/AVHRR images, obtained from the Satellite Active Archive (SAA) for the year 1995. Pre-processing of the data included transformation of the data files to ILWIS format followed by radiometric and geometric corrections, through the use of a special computer program (NPR1b). The presence of clouds in some images led to a reduction of the number to 25.

The NDVI values were calculated through the standard formula using channels 1 and 2. The average NDVI of the main irrigation systems in the Zayandeh Rud Basin for each image was then determined through ILWIS GIS operations. The evolution in time of the NDVI values for the individual irrigated areas can then be analysed.

The NOAA NDVI values can also be used in the determination of the size of the actual irrigated areas of the principal systems. However, calibration of the method proved necessary. Through the use of GIS operations on a Landsat 7 image (August 1, 1999), the actual irrigated areas in the Borkhar, Abshar Left and Right, Nekouabad Left and Right , were determined accurately for that particular date. Five NOAA images were then selected for the period 1 July until August 30, 1999. This made it possible to establish regression relations linking NOAA NDVI values to the size of the net irrigated systems, which can then be used for the analysis of the 1995 data set.

The methods discussed in this paper will be applied to a longer NOAA time series from 1995 until 2000, together with other applications such as determination of evapotranspiration, biomass and irrigation performance.

Monitoring NDVI of the main irrigation systems with NOAA/AVHRR During 1995.

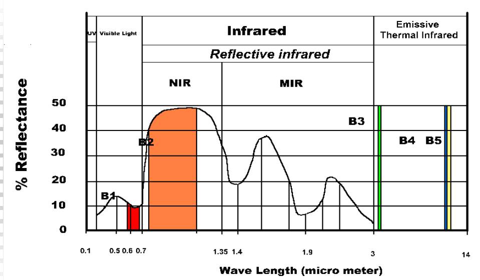
Toomanian Norair, M. Akbari, A. Gieske

OUTLINE

- Introduction
- Methods
- Results
- Discussion
- Conclusion

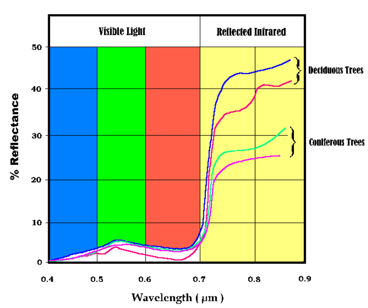
INTRODUCTION

Sun Emitted Radiation



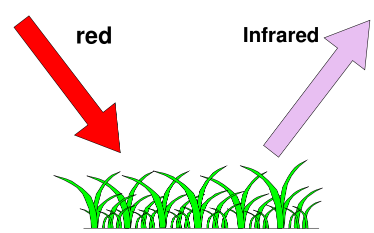
An idealised spectral reflectance curve from a healthy vegetation

AVHHR NOAA 14



Generalized spectral reflectance curves

for deciduous (broad-leaved) and coniferous (needle-bearing) trees.



OBJECTIVES

- Irrigation Area
- Irrigation Performance
- Evapotranspiration
- Biomass
- Temporal changes in Irrigation Systems

METHODS

Image Acquisition

- Internet Sites (www.saa.noaa.gov)
  - Satellite Active Archive. 40 Images were processed. (Some were discarded because of clouds)
- Pre Processing
  - Radiometric Correction
  - Geometric Correction

Image Processing: Continued…

- Processing
  - Geo-referencing
  - Crossing operation
    - Calculation of Irrigated area
    - Calibration against Landsat

Vegetation Index

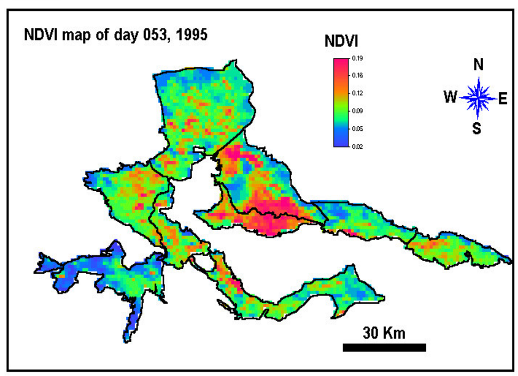
- Is an algebraic combination of reflectance measurements in two or more spectral channels.
- Is a common spectral index that identifies the presence of chlorophyll.
- Is composed of reflectance in the red spectral region (0.62 – 0.7 micr.m NOAA) and a portion (0.7 – 1.1 micro.m NOAA) .

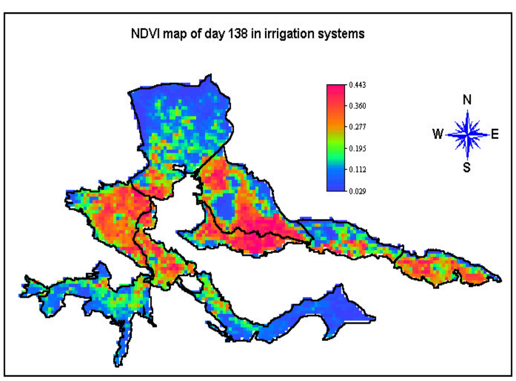
Normalized Difference Vegetation Index (NDVI)

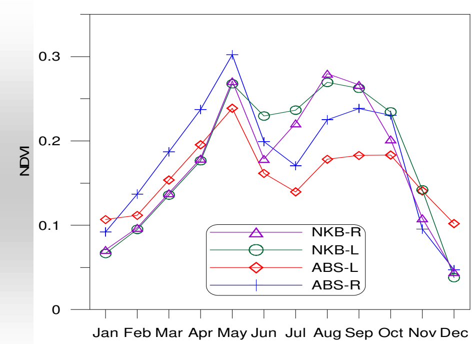
NDVI = (NIR – R)/(NIR + R)

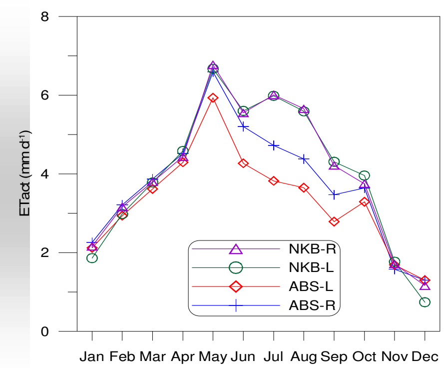
NDVI = (B2 – B1)/(B2 +B1) (NOAA)

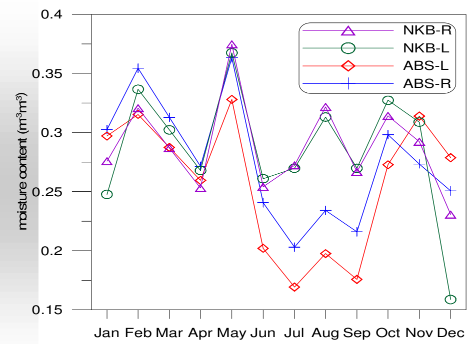
Results

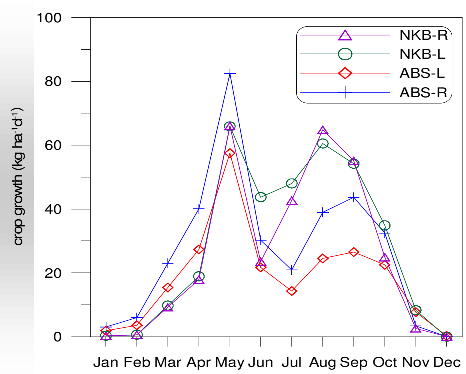


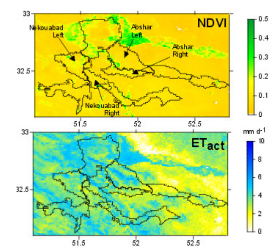


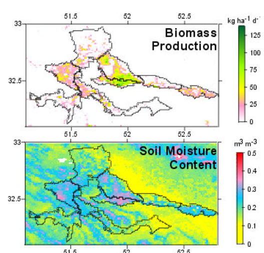






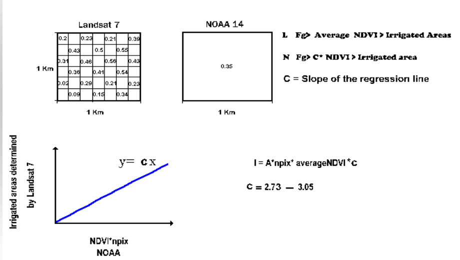






Discussion

Calibration of NOAA against Landsat images



CONCLUSION

- Up scaling from Landsat to NOAA pixel size is required for reliable results.
- Time curves and tables of parameters in every Irrigation System have been made for 1995. The analysis will be extended to 1996-2000.
- The method leads to financial saving and reduction of expenses, because NOAA-14 images are free of charge.

Exploring field scale salinity using simulation modeling, example for Rudasht area, Esfahan Province, Iran

M. Akbari

Esfahan Agricultural Research Center

One-third of the irrigated land in the major irrigation countries is affected by salinity or is expected to become so in the near future. A rapid assessment to evaluate the effect of changes in irrigation water quality and quantity is applied for the Rudasht irrigation project in Iran. This was performed by using a physically based, well-tested simulation model for crop growth, water and salt transport at field scale. Results indicate that the current practice of 900 mm annual irrigation application rates for cotton, given the current salinity level of 4 dS m^{-1}, is close to the optimal one. Graphs are presented to evaluate the effect of different combinations of application rates and salinity levels on yields, and the water and salt balance. It was concluded that the methodology presented here is versatile, rapid, and transferable to other conditions. Moreover, the method produces output at a high spatial and temporal resolution over a long time frame.

Exploring Field Scale Salinity Using Simulation Modeling

by
Akbari, Torabi, Droogers

Esfahan Agricultural Center

Outline

- Introduction
- Material and methods
- Results
- Conclusions and recommendation

Introduction

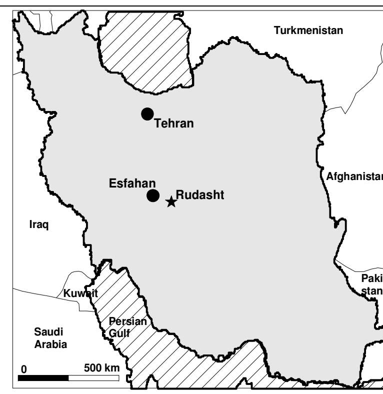
- Salinity is a major problem in the world .
- One third of the irrigated land in the major irrigation countries affected by salinity
- Changes in water quality and quantity availability
- how to manage the problems related to saline irrigation water?

Materials and methods

- Study area
- Simulation model
  - easy to do multiply scenarios
  - results of all terms of water and salt balance
- Input data
- Scenarios

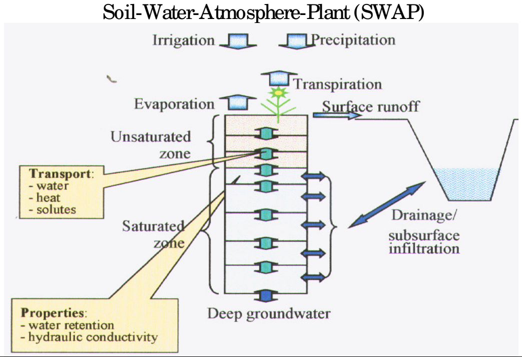
Study area

- The Rudasht irrigation project (52° lon., 32.5° lat) is located east of Esfahan.
- Altitude about 1500 m
- Temperatures from 30° C in summer Down to 3° C in Winter
- Average annual precipitation is 120 mm
- Main crops are winter wheat and barley, sugerbeet, cotton and melons



Simulation model

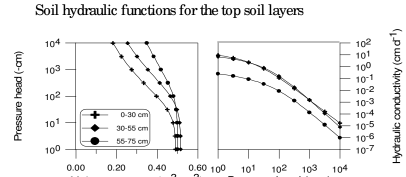
Soil-Water-Atmosphere-Plant (SWAP)



Input data

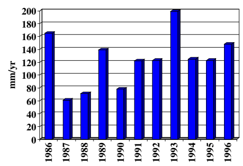
- Soils
  - Soil hydraulic function:
    - Water retention
    - Hydraulic conductivity

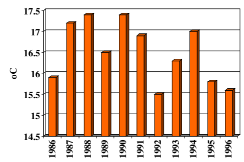
Soil hydraulic functions for the top soil layers



Climate data

- Monthly meteorological data was available for 11 years.
- Climate data from Kabutarabad station in the vicinity of the rudasht irrigation scheme.





Crops

- Main crops in the area are:
  - Winter wheat
  - Barley
  - Sugar beet
  - Cotton
- For this study we selected cotton
  - Seeded at the beginning of April
  - Harvested at beginning of October
  - Potential yields is around 5000 kg/ha

Irrigation

- Normal irrigation is between 800-1000 mm
- Application rates about 100 mm
- Water quality was poor between 2 and 6 dS/m

Baseline

- The baseline is used as a reference
- Irrigation input 900 mm
- The salinity of the irrigation water 4dS/m
- No drainage considered
- A period of 10 years was considered

Scenarios

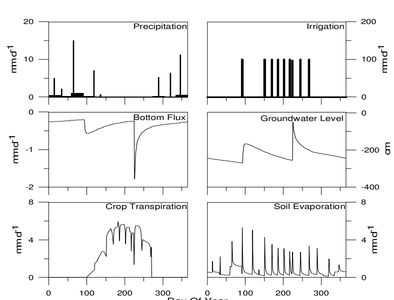
- The first scenario is the baseline scenario
- Effect of different water management
  - Changes water quantity
  - Changes water quality
  - Changes water quantity and quality
- And their Effect on :
  - Water balance
  - Salt balance
  - Crop yields

Results, baseline

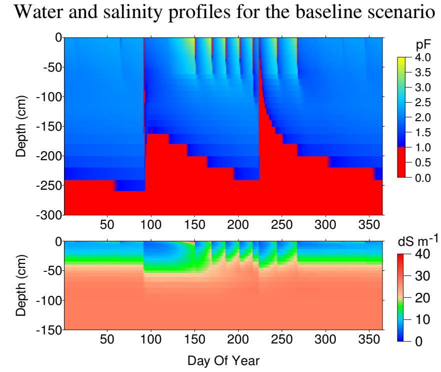
- Annual water for baseline scenario at equilibrium stage, 900mm, Ec 4 dS/m

	Potential mm	Inflow mm	Outflow mm
Transpiration	922		640
Evaporation	1145		246
Precipitation		118	
Irrigation		900	
Bottom flux			130
Surface runoff			0
Mass balance error			2
Total	2067	1018	1018

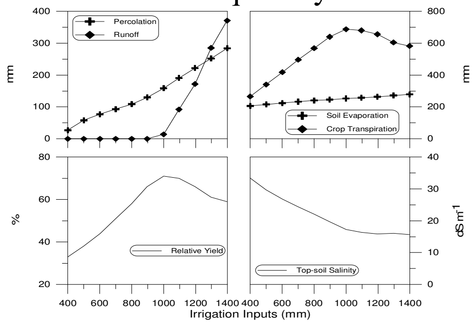
Annual water balance for the baseline scenario



Water and salinity profiles for the baseline scenario



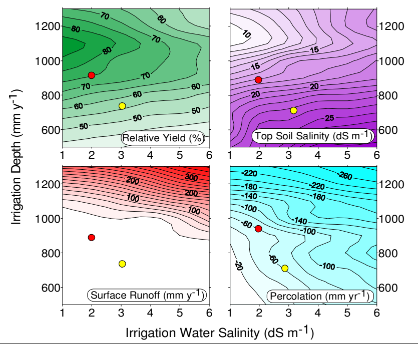
Result water quantity scenario



Results water quality scenario

dS m^{-1}	PCP	Irr	F_{bot}	Runoff	T_{pot}	T_{act}	E_{pot}	E_{act}	Yield	Salinity
1	118	900	-27	0	922	742	1145	247	77	15.6
2	118	900	-62	0	922	709	1145	248	73	17.6
4	118	900	-130	0	922	640	1145	246	66	19.7
6	118	900	-197	72	922	496	1145	245	51	22.7

Combined effect of irrigation water quality and quantity



Conclusions and recommendations

- Simulation models very useful:
  - many scenarios in short time
  - economical
- Field experiments to check model
- Repeat for other crops
- Consider basin scale, not only field scale

The use of Saline water for crop prodution

M. Feizi

Esfahan Agricultural Research Center, Iran

Yield response to different irrigation water salinity, including blending, cyclic and plant growth stage in fix plots using barley-Cotton-sunflower rotation were studied.

Treatments including irrigation water of 2.8(RW), 6.2(MW) and 10.3dS/m(DW) are as follows:

T1= Irrigation with RW for all irrigations.

T2= Irrigation with MW for all irrigations.

T3= Irrigation with DW for all irrigations.

T4= Irrigation with RW from planting to seedling establishment, followed by MW.

T5= Irrigation with RW from planting to seedling establishment, followed by DW

T6= Cyclic irrigation with RW and MW starting with RW.

T7= Cyclic irrigation with RW and DW starting with RW.

For all Crops, relative yield(RY) with respect to T1 was lowest in T3 treatment. For barley and cotton RY in the decreasing order obtained in T1, T6, T4, T2, T7, T5 and T3 treatments. T6 RY was 85 and 87 percent for barley and cotton, respectively. Ry trend for sunflower were slightly different from the other two crops. Ry for T6 was 98 percent.

Regression analysis showed that for sunflower and barley the weighted average irrigation water salinity (ECiw) was the best predictor for yields. However, in prediction of seed-cotton yield beside ECiw, the average soil salinity at sowing, germination and harvest were effective.

Comparing ECe and SAR at sowing, harvesting and germination in different treatments showed that, In general the ECe and SAR at germination decreased. After germination the salinity of irrigation water and the initial soil salinity were the most important factor in ECe and SAR. However the ECe and SAR were lower in T1 and T6 Treatments.

THE USE OF SALINE WATER FOR CROP PRODUCTION

Mohammad Feizi

Introduction

- Increasing Population
- Industrial expansion
- Increasing household consumption
- Lack of fresh water in dry regions
- Consideration of using saline irrigation water
- Various strategies for substitution of saline irrigation water for fresh water

Materials and Methods

- T1-Irrigation with RW (2.8 dS/m) for all irrigations.
- T2-Irrigation with MW(6.2 dS/m) for all irrigations.
- T3-Irrigation with DW(10.3 dS/m) for all irrigations.
- T4-Irrigation with RW from planting to seedling establishment, followed by MW.
- T5-Irrigation with RW from planting to seedling establishment, followed by DW.
- T6-Cyclic irrigation with RW and MW starting with RW.
- T7-Cyclic irrigation with RW and DW starting with RW.

The soil physical properties at the experiment site.

Soil depth	Soil texture	FC	PWP	ρb
cm		g/g	g/g	g/cm3
00-20	clay loam	30.3	15.6	1.4
20-40	clay loam	32.2	16	1.3
40-60	clay loam	33	18	1.4
60-80	Clay	39	19	1.34

The soil chemical properties at the experimental site.

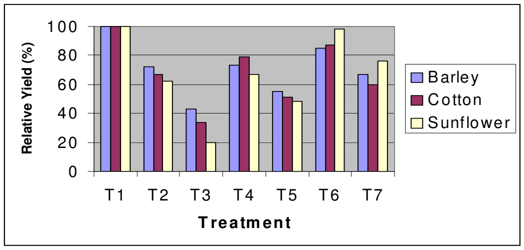
Soil property	Depth (cm)		
	00-20	20-40	40-60
Ece (dS/m)	6.2	5.2	5.9
SP (gr/gr)*100	46	47	52
pH	7.6	7.6	7.7
Na^+ (me/l)	27	21	34
$Ca^{++}+Mg^{++}$ (me/l)	55	51.2	50
So_4^{2-} (me/l)	51	53	67
cl^- (me/l)	27	14.4	12
HCo_3^- (me/l)	3	2.8	2.6
Gypsum (me/100 gr soil)	65	80	35
NaX (me/100 gr soil)	2.6	2.1	3
CEC (me/100 gr soil)	14.5	14	17
SAR $(me/l)^{1/2}$	5.2	4.2	6.8
ESP %	18	15	17.6

The chemical properties of different source of irrigation water qualities

Water source	Eciw	pH	Na	Ca+Mg	So4	cl	HCo3	SAR
	(dS/m)		me/l	me/l	me/l	me/l	me/l	
RW	2.8	7.7	17	13	11	14	3.8	6.7
MW	6.2	8	43	20	14	46	4	7.5
DW	10.3	8.1	77	31	25	79	4.3	19.6

Results

Relative yield of crops



ECiw	**2.7**	**6.2**	**10.4**	**4.9**	**7.6**	**4.3**	**6.3**	**Barley**
ECiw	**2.6**	**6.1**	**10.5**	**5.6**	**9.1**	**4.2**	**6.5**	**sunflower**
ECiw	**2.9**	**6.3**	**10.2**	**5.4**	**9.0**	**4.6**	**6.6**	**Cotton**

Regression equations

✶Sunflower

- RY (gy)= 130-9.85(ECiw) R^2=0.67
- RY (pp)= 124.1-6.61(ECiw) R^2=0.67
- RY (df)= 113.8-4.47(ECiw) R^2=0.58
- RY (ph)= 113.6-5.3(ECiw) R^2=0.83

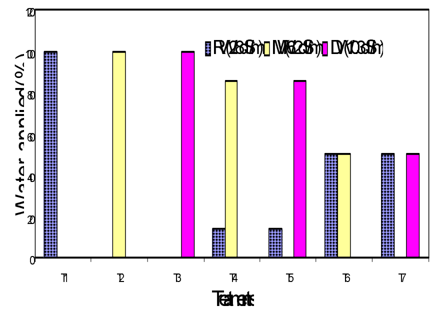
Regression equation

✶Cotton

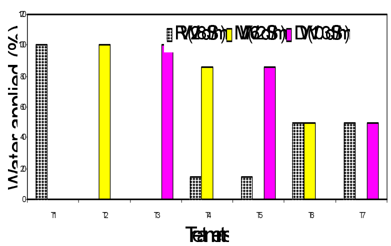
- RY (ly) =154.6-5.8(ECiw)-4.9(ECea) R^2=0.65
- RY (ph) =119.1-7(ECiw) R^2=0.8

✶Barley

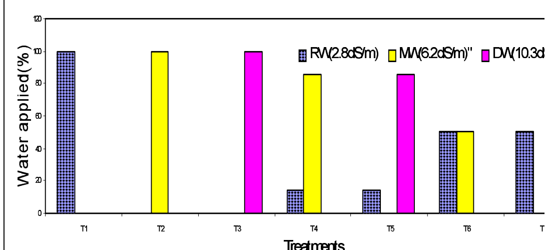
- RY (gy) =115.51-7.38(ECiw) R^2=0.51
- RY (ph) =112.7-4.43(ECiw) R^2=0.51
- RY (kh) =120.7-3.28(ECiw)-1.32(ECea) R^2



Different irrigation water quality and percentage (Barley)



Different irrigation water quality and percentage (Cotton)



Different irrigation water quality and percentage (Sunflower)

Conclusion

- ✶ **Comparing intermittent irrigation of RW and MW(T6)with river water(T1) resulted in yield reduction of only 13% for cotton,15% for barley and 2% for sunflower.**
- ✶ **Use of fresh water up to germination and establishment and then use of MW(T4)resulted in yield reduction of 21%for cotton,27%for barley and 33% for sunflower.**
- ✶ **Use of MW and DW(T5)resulted in yield reduction of 45% for barley,49% for cotton and 52% for sunflower.**

Conclusion Continued...

- ✶ In order to maintain salt balance in the soil profile,treatments T1 and T6 are recommended.
- ✶ Treatments T4 and T2 can be considered,if leaching fraction is use during or at the end of growth period.
- ✶ For sustainable agriculture appropriate LF should be considered.
- ✶ By using T6 about 50% of fresh water could be saved and meantime yield maintained at accepted levels.

Groundwater Chemistry of the Lenjanat District, Esfahan Province, Iran

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Esfahan Agricultural Research Center, Sri Lanka

A hydrochemical analysis is made of the groundwater and surface water in the Lenjanat District, which lies between Esfahan and Chadegan Dam along the Zayande Rud. The analysis is based on two data sets, both kindly made available by the Ministry of Energy (Esfahan Regional Water Organization). The first one consists of chemistry data for over 750 samples from wells, qanats and springs in the area, collected from 1986 – 1997. The second comprises 328 analyses of Zayandeh River water, collected at six stations along the river during the period 1991-1998.

The evolution of the hydrochemical facies is described through the use of Piper and Stiff diagrams, while source rock deductions are made by means of the program WATEVAL (Hounslow, 1995). Spatial distribution of the EC values in the district is determined through application of Kriging methods and examples are given for temporal changes in EC at a few representative locations.

It is shown that the groundwater is of a limestone origin. However, because of frequent contacts with gypsum deposits, gypsum dissolution is strongly affecting the groundwater chemistry of most samples.

Furthermore, the analysis reveals that there is a natural groundwater flow northward which seeps into the Zayandeh Rud eventually. The irrigation return flow component is added to this. Although both flow components are small, they carry a significantly higher solute load than the Zayandeh Rud in this stretch of the river. Thus they change the river's chemical composition as it flows through the Lenjanat District.

Finally, it would appear that so-called mixing cell methods may be used to quantify natural groundwater seepage and irrigation return flow components, provided information is available with respect to their chemical composition. Groundwater flow and mass transport modelling would be of practical importance in the study of surface water-groundwater interactions along the Zayandeh Rud.

Groundwater-Surface water interaction in the Lenjanat District, Esfahan province, Iran

M.MIRANZADEH

OUTLINE

- **Introduction**
- **Groundwater in Esfahan Province**
- **Groundwater Chemistry of the Lenjanat District**
- **Comparison with Surface Water Chemistry Zayandeh Rud**
- **Mixing Cell Method**
- **Discussion**

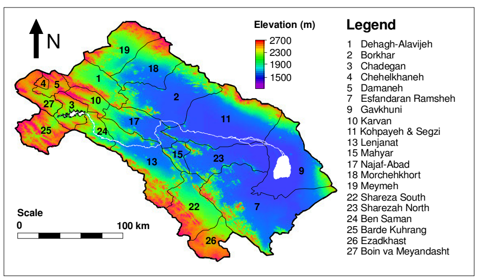
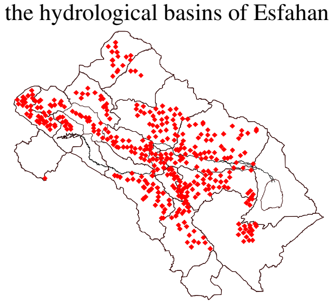


Fig. 1a Hydrological Districts in the Zayandeh Rud Basin. The elevations shown here on a 1x1 km grid, are derived from the digital chart of the world.

Location of observation wells in the hydrological basins of Esfahan



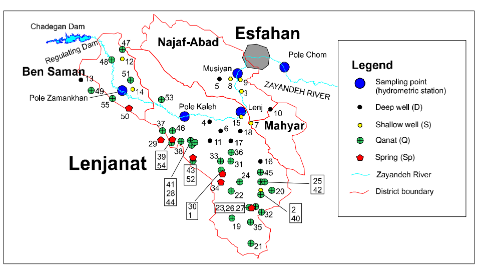


Fig. 1b Location map, showing wells,qanats and springs in the Lenjanat, Ben Saman and Najaf-Abad hydrological subcatchments, plotted on a 5x5 km grid. Also shown are the surface water sampling points.

Groundwater Chemistry of the Lenjanat District

- **Data sets**
- **Quality checks**
- **Hydrochemical facies**
- **Comparison with surface water**

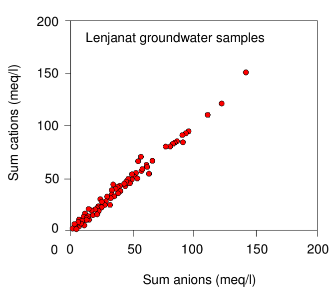


Fig. 2 Scatter diagram of the sum of the anions against the sum of the cations (groundwater samples Lenjanat).

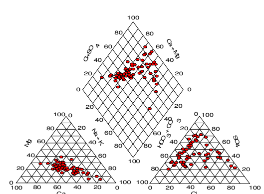


Fig. 5 Piper diagram showing average chemical composition of 55 wells in the Lenjanat and Ben Saman hydrological districts (1986-1998).

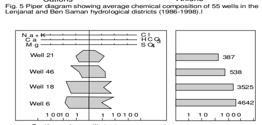


Fig. 6 Stiff diagrams and EC values of average groundwater composition in four wells of the Lenjanat Districts (1986 -1997).

Groundwater quality

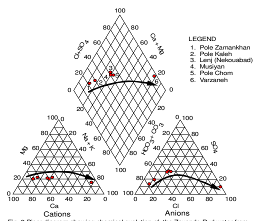


Fig. 3 Piper diagram showing chemical evolution of the Zayande Rud water from Pole Zamankhan towards Varzaneh (averages over the period 1989 - 1997).

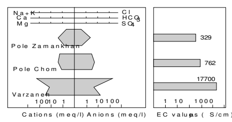


Fig. 4 Stiff diagrams and EC values of average river water chemical composition at three stations along the Zayandeh Rud (1989-1997).

Zayandeh Rud water quality

Table 1 Source rock deductions as determined with WATEVAL (Hounslow, 1995)

			conclusions
1	Langelier index	0.16 average 0.14 stand.dev.	slightly oversaturated with respect to calcite
2	Halite $Na^+/(Na^++Cl^-)$	11% =0.5 78% >0.5 11% <0.5	sodium source other than halite: some ion exchange no reported diapirs in area: no halite dissolution
3	$Mg^{2+}/(Ca^{2+}+Mg^{2+})$	100% <0.5	limestone/dolomite weathering
4	$Ca^{2+}/(Ca^{2+}+SO_4^{2-})$	27% =0.5	gypsum
		40% <0.5	Ca removal: ion exchange/calcite precipitation
		33% >0.5	Ca source other than gypsum: carbonates likely
5	$(Ca^{2+}+Mg^{2+})/SO_4^{2-}$	20% >0.8 and <1.2 80% <0.8 and >1.2	dedolomitization only locally indicated
6	HCO_3^-/sum anions	100% <0.8 generally high sulphate	gypsum dissolution indicated in most cases

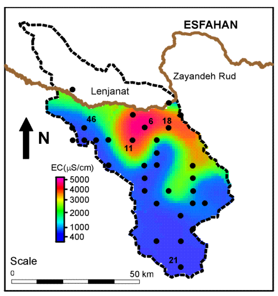
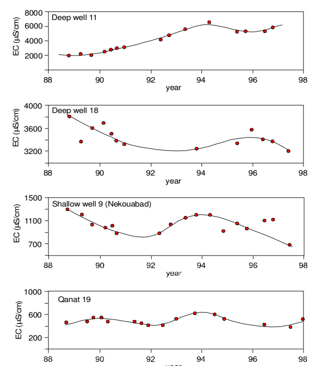


Fig. 8 Kriged map of the EC values in the southern part of Lenjanat District below the Zayandeh Rud, while the variogram model is shown in Fig. 9. A search radius of 20 km was used with pixel size 1 km.

Result of the Kriging Analysis



Long –term trend in the EC of the four sampling points: 11,18,9 and 19

Mixing model for zayande rud stretch

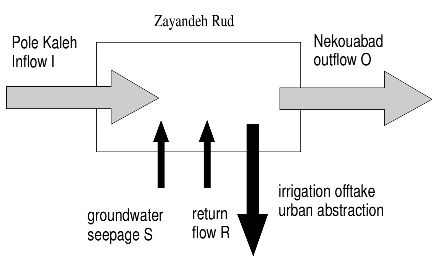
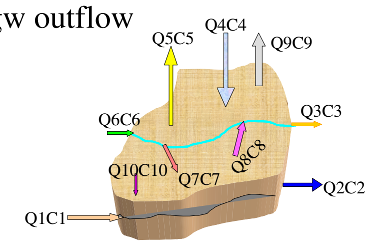


Fig. 11 Conceptual mixing model for the Zayandeh river stretch from Pole Kaleh to Nekouabad.

Table 2 Concentrations and flow rates of the five component conceptual model (the influence of precipitation and evaporation are left out in this example).

Flow component	Q (m^3/s)	EC (µS/cm)	TDS (g/m^3)
Pole Kaleh inflow I	54.0	366	256
Nekouabad outflow O	50.0	575	403
Groundwater seepage S	?	3000	2100
Irrigation/urban G	9.5	471	330
Return flow R	?	2120	1484

1 gw inflow
2 gw outflow



Discussion

- Groundwater is of limestone origin. However, it is strongly affected by gypsum dissolution.
- The natural groundwater flow is towards the North and seeps into the Zayandeh.
- Because the groundwater has a high solute load it changes the chemical composition of the river.
- If the chemical composition of groundwater and surface water components is known, then seepage and return flow can be quantified.

Irrigation in the Basin Context

M. Torabi

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Traditional analyses of irrigation performance, especially the concept of irrigation efficiency, can mislead planners and policy makeres, especially as water availability at the river basin level becomes the primary constraint to agricultural production. In this situation, improving the productivity of water requires rethinking of some basic 'facts' about irrigation performance and new ways of water resource management.

In the "Sustainable water and irrigation management in Zayandehrood basin" collaborative project, the basin issues are treated at three different levels. Basin scale, regarding water alloction between different users (i.e. Urban, industrial, and agricultural); Irrigation scheme, considering cropping patterns and overall irrigation management; Field scale with respect to detailed soil-water-plant relationships. As a firt step, the present trend in water resource problems within the basin will be assessed. In the next step, the interactions between basin, irrigation scheme, and field issues for numerous scenarios will be evaluated using modern technology such as GIS, satellite images and computer models. Finally, based on the realities in the basin, the most appropriate policies for water resource management could be made to alleviate the basin problems.

Irrigation in the Basin Context

M. Torabi

Outline

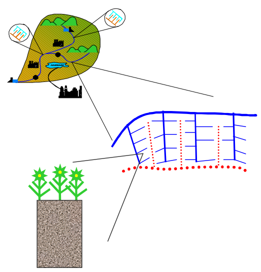
- Why irrigation in the basin context
- How to study
- Examples of studies at different scales
- Examples of linkages
- Conclusions

Why Irrigation in the Basin Context?

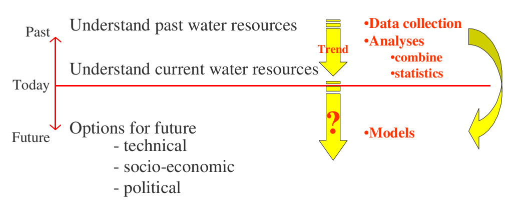
Basin scale
- water allocation between different users

Irrigation scheme
- cropping pattern and overall irrigation management

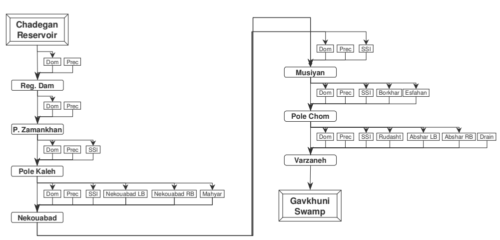
Field scale
- detailed soil-water-plant relationships



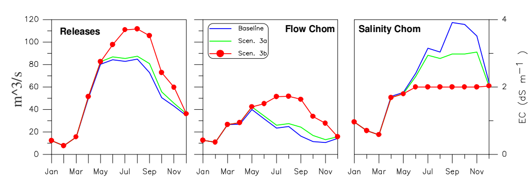
Sustainable water management



Basin Scale Analyses
Water and Salinity Basin Model (1)



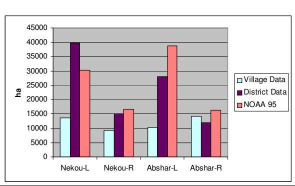
Basin Scale Analyses
Water and Salinity Basin Model (2)



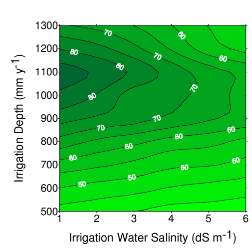
- Scen 3a = how much additional water for Rudasht
- Scen 3b = same as 3a but EC < 2 dS/m

System scale
Irrigated areas

- System scale analyses require cropping pattern data
  - Data already collected
  - Remote Sensing

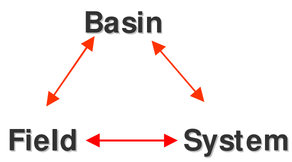


Field scale
SWAP model

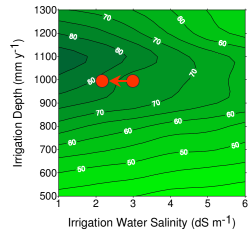


- Yield response function on water quantity and quality
- Derived from SWAP simulations
- Standard conditions for cotton

Irrigation in the basin context



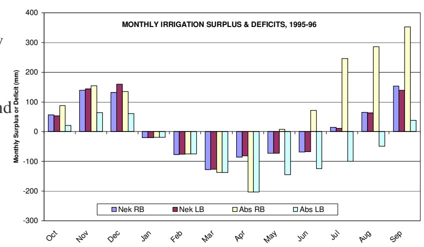
Basin - field interactions
Basin Water Salinity Model



- Baseline
  - potential yield 74%
- Scenario 3b
  - potential yield 79%
- Yield increase 7%
- Releases +23%

Basin - system interactions
Supply and Demand

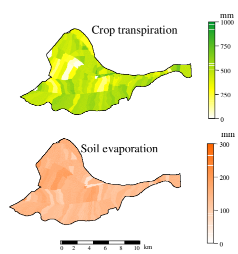
- Supply: Streamflow data
- Demand: Cropwat and cropping pattern



System - field interactions
Aggregated SWAP modeling (1)

- Objective:
  - Detailed Soil-Water-Salt analysis at system level
- Aggregated SWAP
  - Define subunits:
    - crop
    - soil
    - irrigation practice
    - ...

System - field interactions
Aggregated SWAP modeling (2)



Conclusions, future activities

- Importance of irrigation in the basin context
- Models are useful tools for scenario analyses for water resources management

- Strengthen linkage between different scales
- More scenario analyses

Influences of changes in water quality and quantity of cotton irrigation water on optimal cropping pattern of Rodasht region of Isfahan

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Esfahan Agricultural Research Center, Iran

Irrigated agriculture is included, nearly 17 percent of all over the agricultural areas in the world. Agricultural productions of these areas are nearly 34 percent of total agricultural production in the world. However, It is estimated that roughly one - third of the irrigated land in the major irrigation countries is already badly affected by salinity or is expected to become so in the near future. Therefor enough agricultural water for responding to agricultural water demand is scarcity in these regions and water resource management is a very important problem for economic programmers in many countries.

In this study, influences of changes in water quality and quantity of cotton irrigation water on yield and profitably of optimal cropping pattern are studied in Rodasht region of Isfahan by using data of soil - water - Atmosphere - Plant (SWAP) model for cotton, and selected mathematical programming method for region. The other data including cross section and time series data used in this study were collected using interviewing of farmers and library data.

Results showed changes in water quality and quantity of cotton could affect on production and cultivated area of other major crops including wheat, barley and sugar beet. Thus, total cropping revenue of Rodasht region of Isfahan may change.

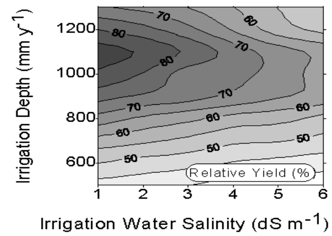
Influences of changes in water quality and quantity of cotton irrigation water on optimal cropping patterns of Rudasht region of Isfahan

by

A. Solaimani Pour and A.R. Nikooie

Agricultural Economic Department Of Isfahan

Combined effect of irrigation water quality and quantity on crop yield



Source: Droogers et al (2000)

Materials and Methods

- **Study area**
  - Rudasht Region of Isfahan Province
- **Input Data**
  - Cross section data using Simple Random Sampling Method and interviewing with farmers
  - SWAP data using Soil - Water -Atmosphere - Plant model for cotton
  - Time series data using library data.

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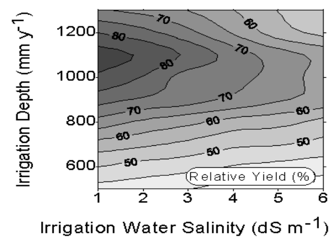
Combined effect of irrigation water quality and quantity on crop yield



Source: Droogers et al (2000)

Modeling and Analysis

- Linear Programming (LP) Model
  - **Objective function**

    Maximize: Z = C'X
  - **Subject to:**

$$AX\ (\leq = \geq)\ B$$

$$X \geq 0$$

- Analysis
  - Cluster Analysis

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- Example of LP for this study

Max C1X1+ C2X2+ C3X3+ C4X4+ C5X5

Subject to

>> (1) a11X1+ a12X2+ a13X3+ a14X4+ a15X5 <= b1
>> (2) a21X1+ a22X2+ a23X3+a24X4 <= b2
>> (3) a31X1+ a32X2+ a33X3+ a34X4 <= b3
>> (4) a41X1+ a42X2+ a43X3+a44X4 <= b4
>> (5) a51X1+a52X2+ a53X3+ a54X4 <= b5
>> (6) a61X1+ a62X2+ a63X3+ a64X4 <= b6
>> (7) a71X1+ a72X2+ a73X3+ a74X4 <= b7
>> (8) a81X1+ a82X2+ a83X3+ a84X4 <= b8

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Activities and Constraints of LP Model in this study

- **Activities**
  - X1 = Wheat
  - X2 = Barley
  - X3 = Cotton
  - X4 = Sugar beet
  - X5 = Fallow
- **Constraints**
  - **b1 = Land size**
  - **b2 = Ground preparing**
  - **b3 = Sewing**
  - **b4 = Fertilizer**
  - **b5 = Water**
  - **b6 = Toxics**
  - **b7 = Weeding**
  - **b8 = Harvesting**

Table 1- Cluster Analysis Resultes for Rudasht Sample Farms

Homogenus Group	No. of Case	Farm Size Mean (ha)	Minimum Farm Size (ha)	Maximum Farm Size (ha)	Gross Margin Mean (Rial)	Relative Yield Mean of Cotton
1	21	1.42	0.30	2.8	4152640	90%
2	16	4.52	3.90	6	10372730	70%
3	15	8.62	7	9.8	20051800	60%

Source: Resultes of this study

LP in Homogenus Groups of this study

- Group 1 with 1.42 Farm Size

Max 174961X1+ 100295X2+ 637229X3+ 467562X4+ 1X5
>>Subject to
>> (1) 1X1+ 1X2+ 1X3+ 1X4+ 1X5 <= 1.42
>> (2) 18305X1+ 18125X2+ 27799X3+ 28659X4 <= 31315
>> (3) 24771X1+ 14295X2+ 21826X3+ 10735X4 <= 37814
>> (4) 25319X1+ 21151X2+ 22417X3+ 33564X4 <= 36669
>> (5) 31071X1+ 23916X2+ 56035X3+ 60027X4 <= 55336
>> (6) 4689X1+ 3210X2+ 11672X3+ 8644X4 <= 28712
>> (7) 24744X3+ 43093X4 <= 48738
>> (8) 11836X1+ 14130X2+ 52719X3+ 92971X4 <= 50676

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LP in Homogenus Groups of this study

- Group 2 with 4.52 Farm Size

Max 202462X1+ 93385X2+ 500504X3+ 286179X4+ 1X5
>>Subject to
>> (1) 1X1+ 1X2+ 1X3+ 1X4+ 1X5 <= 4.52
>> (2) 21738X1+ 11000X2+ 27125X3+ 27125X4 <= 134001
>> (3) 24210X1+ 10400X2+ 22250X3+ 14475X4 <= 132750
>> (4) 20411X1+ 16357X2+ 25979X3+ 33312X4 <= 214000
>> (5) 42918X1+ 52857X2+ 30333X3+ 48500X4 <= 186433
>> (6) 6665X1+ 4800X2+ 3391X3+ 8458X4 <= 27376
>> (7) 22500X4 <= 60000
>> (8) 15313X1+ 10000X2+ 35666X3+ 103750X4 <= 270000

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LP in Homogenus Groups of this study

- Group 3 with 8.62 Farm Size

Max 252957X1+ 161212X2+ 500504X3+ 286179X4
>>Subject to
>> (1) 1X1+ 1X2+ 1X3+ 1X4+ 1X5 <= 8.62
>> (2) 16287X1+ 17312X2+ 27125X3+ 27125X4 <= 263000
>> (3) 21619X1+ 14854X2+ 22250X3+ 14475X4 <= 208750
>> (4) 23399X1+ 12235X2+ 25979X3+ 33312X4 <= 279750
>> (5) 33020X1+ 20000X2+ 30333X3+ 48500X4 <= 630000
>> (6) 3884X1+ 1750X2+ 3391X3+ 8758X4 <= 73800
>> (7) 22500X4 <= 200000
>> (8) 13584X1+ 13490X2+ 35666X3+ 103750X4 <= 900000

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Table 2- LP Models Results for Group 1

Cultivated area	*Wheat (ha)*	*Barley (ha)*	*Cotton (ha)*	*Sugar Beet (ha)*	*Fallow (ha)*	*Gross Margin (Rial)*
Relative Yield (%)						
100	0.08	0	0.94	0	0.4	6150750
90	0.36	0	0.88	0	0.18	5501730
80	0.59	0	0.83	0	0	4919470
70	0.59	0	0.83	0	0	4222190
60	0.97	0	0.06	0.39	0	3691900
50	0.96	0	0	0.42	0.04	3662900

Source: Results of this study

Table 3- LP Models Results for Group 2

Cultivated area	*Wheat (ha)*	*Barley (ha)*	*Cotton (ha)*	*Sugar Beet (ha)*	*Fallow (ha)*	*Gross Margin (Rial)*
Relative Yield (%)						
100	0	0	4.52	0	0	30189080
90	0	0	4.52	0	0	26405930
80	0	0	4.52	0	0	2262780
70	0	0	4.52	0	0	18839630
60	0	0	4.52	0	0	15056440
50	0	0	2.92	1.60	0	11860830

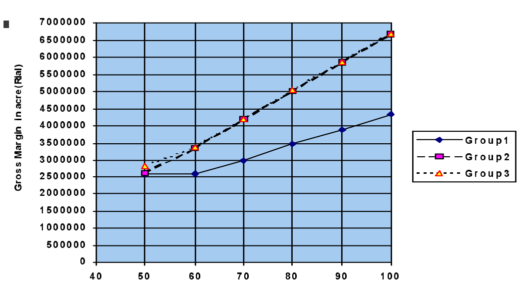
Source: Results of this study

Table 4- LP Models Results for Group 3

Cultivated area	*Wheat (ha)*	*Barley (ha)*	*Cotton (ha)*	*Sugar Beet (ha)*	*Fallow (ha)*	*Gross Margin (Rial)*
Relative Yield (%)						
100	0	0	8.62	0	0	57572980
90	0	0	8.62	0	0	50358220
80	0	0	8.62	0	0	43143450
70	0	0	8.62	0	0	35928680
60	0	0	8.62	0	0	28713820
50	0.75	0	0	7.87		24420650

Source: Results of this study

Figure of Relationship Between Gross Margin and Cotton Relative Yield



Results

- Gross margin of optimal croping patterns are greater than farmer croping patterns in the Rudasht region
- With icreasing of cotton relative yield in acre, gross margin of optimal croping patterns will increase
- With decreasing of cotton relative yield in acre, the cotton will exit from optimal croping patterns
- With icreasing in land size, we see economic return to scale

Agricultural Economic Department Of Isfahan

Managerial aspects of irrigation

H. Murray Rust

International Water Management Institute, Sri Lanka

One of the most important elements of sustainable and productive irrigated agriculture is the provision of reliable and predictable deliveries of water and other inputs. We express this concept in the phrase "level of service". A high level of services means that people can use water much more efficiently than if the level is unreliable.

Managing water for irrigated agriculture involves a long chain of actions by different people: those responsible for design and construction of water storage and diversion of facilities, those who operate water control infrastructure as dams and regulators, those who manage water at secondary irrigation systems, those who do it at tertiary or village level and, eventually, the individual farmer. If there is uncertainty or disruption at one upstream point, it will be felt by everybody downstream of that location. There is also a parallel system of information about supply and demand that is an essential part of the management system.

In well-managed systems we have a clear set of targets which everybody knows and understand. If targets are met, then everybody will be satisfied with the level of service.

There is a different set of management requirements that also affect efficient use of water. These are the policy and institutional arrangements that define the rights and roles of each person involved in water management. Much of this responsibility lies with government, either at national or at basin level, because they must define water rights, policy for pricing water and charging for services, and the relative responsibilities of different agencies. Experience in other countries indicates that when water users themselves are involved in the process of determining rights and responsibilities the end result is a set of organizations that operate more effectively.

As water gets increasingly scarce efficient water management is essential. This requires that improvements in management using targets and feedback must be combined with improved water management institutions. If levels of service are high, then payments for irrigation service are also high and the system can move forward into the future with harmony and confidence.

Managerial Aspects of Irrigation

Hammond Murray-Rust
International Water Management Institute

IAERI EARC IWMI

Contents of the presentation

- Level of Service
- Surface Water Management
- Groundwater Management
- Salinity Management
- Institutional and Legal Dimensions

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Level of Service

- Inputs are delivered according to a known schedule at the amount and frequency that users expect
- *Targets* define the level of service
- *Tolerances* define the permitted deviation
- The best service occurs when there is a contract or clear agreement among suppliers and users at each transfer point

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Surface Water Management

- At each transfer point there needs to be a clear level of service agreement between the supplier and the user
- The transfer may be within the same organization or it may be between different organizations

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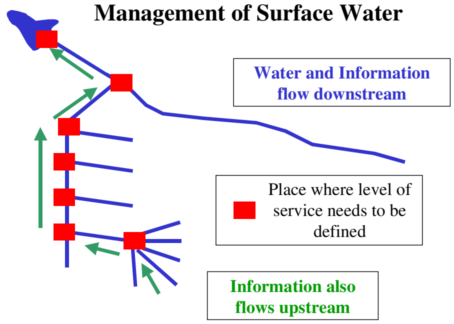
Management of Surface Water



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Management of Groundwater

- Individual access to a common resource makes management very difficult
- Decision-making is individual, and there are no transfer points
- Groundwater may or may not be used with canal water

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Management of Groundwater

- Some regulation is possible through a system of water permits which limit the size and number of tubewells but it is difficult to enforce
- Groundwater districts are more effective: users monitor groundwater levels to ensure that extraction rates of water do not lower water tables below an agreed level.

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Management of Salinity

- Irrigation always leads to increased salinity
- Salt is conservative: once it is in the soil or groundwater system it is very difficult to remove it
- Efforts to keep salt content low in one location will mean more salt elsewhere, so it requires system level management
- Management of salinity requires more specialized monitoring

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Management of Salinity

- Management of salinity requires agreed targets for salinity levels in downstream locations: this will determine on-farm management practice
- Farmers need to know the level of salinity of their irrigation water so that they know how much leaching they must provide
- Consistent levels of salinity are easier to manage than variable levels

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Institutional and Legal Aspects

- The best managed system are those where water users are fully involved in all steps of management: planning, water allocation and distribution, maintenance, monitoring and enforcement
- This requires federated water user organizations and groundwater districts with full legal status
- Many countries are attempting to do this through a program of management transfer from government to water user groups

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Institutional and Legal Aspects

- Legal elements important for improved management include the following:
  - **clear system of water rights, preferably transferable**
  - **clear standards for level of service, groundwater extraction rates and salinity levels**
  - **clear mechanisms for resolving disputes**
  - **enforceable penalties for cases where agreed rules are broken by either suppliers or users**
  - **agreed methods for setting and collecting fees from water users related to level of service**

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Feedback from workshop

1. **Supply and demand.** Demand is based on net demand, without considering efficiency. This is not true. It is recommended that an appropriate efficiency should be included (maximum reachable efficiency).

2. **Productivity of water**. The following topics are missing:
   - Environmental problem of Gavkhuni swamp and the required demand of 12 MCM per year.
   - Economical concerns of productivity of water are not the only things to be considered. If we do not deliver sufficient water to the downstream users of the basin, we should face expansion of the Kavir desert and more salinity and alkalinity problems as well as social conflicts.
   - The role of water management in reduction or increase of water delivery during wet and dry years and directing farmers to a planned consumption of water should be considered.

3. **On sustainable management.** Average volume of annual water can not be a good criterion. It is necessary to have the yearly accessible volume of water and concerning planning the probably fluctuations should be considered.

4. **Deficit irrigation** should be considered by the project based on the guidelines by the national committee of the ICID in Iran. For example a reduction of 20% of water (1000 to 800 mm) will reduce yields by 5%.

5. **Underground reservoirs** can be used in some upstream parts of the basin. During dry years water can be delivered to the farmers from these underground reservoirs. Obviously, in wet years sufficient water should be delivered to these aquifers.