Farmers response to water scarcity and salinity in a marginal area of Northern Syria

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Farmers response to water scarcity and salinity in a marginal area of Northern Syria

Wassernutzung durch Landwirte in Abhängigkeit von Wassermangel und Salzgehalt des Grundwassers an einem marginalen Standort Nordwest-Syriens

W. Schweers, A. Bruggemann, A. Rieser and T. Oweis

Stichworte
Grundwasser, Zusatzbewässerung, Wassernutzeffizienz, Salzgehalt, Trockengebiete, Syrien
Keywords
Groundwater, supplemental irrigation, water-use efficiency, salinity, dry areas, Syria

Zusammenfassung
Grundwasser ist eine wichtige Resource in Trockengebieten, wird aber oft nicht nachhaltig genutzt. Das Ziel dieser Untersuchung bestand darin, den Wasserverbrauch für die Bewässerung von Winterkulturen im Khanassertal, Nordwest-Syrien zu ermitteln. Das Untersuchungsgebiet, am Rand der syrischen Steppe gelegen, ist mit 209 mm Jahresniederschlag marginal für den Trockenfeldbau. Die Bewässerungsfläche mit Anbau von Gerste (Hordeum vulgare L.), Kreuzkümmel (Cuminum cyminum L.) oder Weizen (Triticum aestivum L. und Triticum turgidum L.) wurde mit GPS vermessen. Zwanzig Prozent wurden im Hinblick auf Wasserverbrauch und Produktivität untersucht. Oberflächenbewässerung (OB) und Beregnung (BR) wurden verglichen. Der durchschnittliche Wasserverbrauch (m^3/ha) unterschiedlicher Kombinationen von Bewässerungsmethoden und Kulturarten war: BR-Gerste (949), OB-Gerste (1447), BR-Kreuzkümmel (273), BR-Weizen (1053) und OB-Weizen (3270).

Abstract
Groundwater is an important resource in the dry areas, but often used unsustainably. The objective of this study was to monitor groundwater use for the irrigation of winter crops in Khanasser Valley, northwest Syria. The study area lies at the border of the steppe and is marginal for rainfed agriculture with 209 mm mean annual rainfall. The irrigated area sown to barley (*Hordeum vulgare* L.), cumin (*Cuminum cyminum* L.) or wheat (*Triticum aestivum* L. and *Triticum turgidum* L.) was surveyed by GPS. Twenty percent of it was monitored for water-use and productivity. The average water-use (m^3/ha) for different combinations of crops and irrigation methods was: sprinkler-barley (949), surface-barley (1447), sprinkler-cumin (273), sprinkler-wheat (1053), and surface-wheat (3270).

1. Introduction

Water resources are under threat in many dry areas of the world with serious problems in developing countries having high population growth rates. In Western Asia, Syria is still relatively gifted with water, since about 15% of the country is part of the Fertile Crescent with good rainfall (more than 350 mm/yr), productive aquifers and the Euphrates River. Irrigation from wells accounts for 60% of the total irrigated area of about one million ha (MAAR, 2001). In some areas, the water table has fallen substantially due to overpumping. For example, 25 km south of Aleppo, an average annual drop of 1.75 m has been observed for the past 20 years (DIEKMANN, 2003).

The Khanasser Valley (Fig.1) is located approximately 80 km southeast of Aleppo. It stretches 20 km between the Jabboul salt lake in the north and the border of the Syrian steppe near Adami village in the south. Basalt plateaus of the Tertiary age border the valley in the east and west. The annual average long-term rainfall in Khanasser Valley is 209 mm with about 53 % probability (BRUGGEMAN, 2004). The deep soils in the central valley have a silt loam to clay loam texture. They are prone to capping and hardening when dry, but when moist and tilled, have a high infiltration rate of more than 30 mm/hr as measured by KASMO (1997) and WILDE (1998). According to the FAO classification system (DECKERS et al., 1998), the dominant soil classes are Luvic Calcisol and Calcic Gypsisol (LOUIS BERGER INTERNATIONAL, 1982).

The similarity index for climate and land use/land cover is high for a large part of the agriculturally used winter rainfall areas in Western Asia and Northern Africa (DE PAUW, 2003). Solutions for improved land and water management developed in the Khanasser valley could thus potentially have a larger impact. The most common production system is barley-livestock. Barley provides the main feed source for small ruminants, mainly sheep, and the most reliable yield under rainfed conditions. In low rainfall years, farmers do not harvest the grain, but let their sheep graze the entire crop. Farmers take the risk to grow some rainfed wheat, which they need for making bread, their staple food. In the last three years, production of cumin has expanded rapidly. About 4 % of the cultivated area in the Khanasser Valley is under irrigation. Surface irrigation is done mostly in the form of basin irrigation. Sprinkler irrigation has become widespread since 3 – 4 years.

Well yields from the marley limestone aquifer are too low for continuous pumping. Wells in the more productive alluvial aquifer are usually quite saline, with electrical conductivities (EC) ranging between 2.5 to 26 dS/m (SCHWEERS et al., 2003). A comparison with five wells observed in the 1960s (MIKHAILOV et al., 1966) indicated that the water table decreased during the main well construction period from 1988 to 1997 (SCHWEERS et al., 2003). In a period of average rainfall from 1999 to 2002, there was no significant change in water levels.

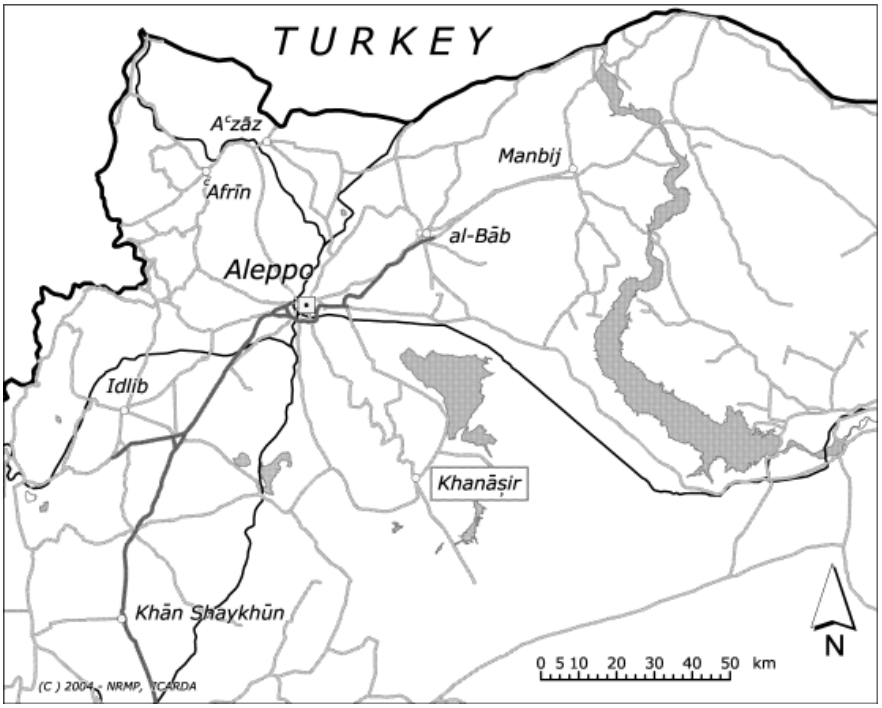

Figure 1:
Overview of Northwest Syria

The objectives of this study were to identify the potential for saving groundwater resources and to quantify the limits of sustainable water use for agricultural production on a watershed level. Since the water levels had remained stable during a period of average rainfall, groundwater recharge appeared to be in balance with groundwater abstractions. It was assumed that, if groundwater abstractions could be determined with sufficient accuracy, the recharge rate and thus the volume of water available for sustainable use could be computed. This would provide the basis for planning a more economical allocation of groundwater resources under conditions of scarcity. In this article, "water-use" is defined as the amount of water abstracted from the aquifer, not the amount actually consumed by crops.

2. Materials and methods

The farmers who cooperated in the resource study were given forms to register the date, the crop, the irrigation method, pump operation hours and, if available, meter readings before and after operating the pump. No incentives were used to convince the farmers to cooperate. Twenty-two out of 156 operative irrigation wells were monitored. These were chosen to represent water-use throughout the valley. Wells and fields were recorded by GPS. During the survey, crops, irrigation methods and other parameters were registered. Arc View® GIS was used to draw maps and compute the areas of the field units.

Records of agronomic variables, such as variety, planting date, seed rate, fertilization, harvesting date, irrigated yield of mapped parcels and rainfed yield of neighbouring parcels complemented the information on water-use. Farmers were visited approximately every two weeks and their observations on irrigation and agronomic practices were recorded. During the interviews, water-use was documented. Date and duration of irrigations were checked and revised together with the farmers if there was a gap in the records. The discharge of wells without water meter was measured by barrel or by installing hosepipes on sprinkler nozzles to collect the water. The electrical conductivity of the irrigation water was measured with a WTW® conductivity meter. The data were registered and processed in a relational database.

Total agricultural water-use for the 2002/03-winter season was determined as follows: Fields were categorized according to the crop and the irrigation method, considered important determinants with respect to water use. There were five possible combinations: Barley-sprinkler irrigation, barley-surface irrigation, cumin-sprinkler irrigation, wheat-sprinkler irrigation and wheat-surface irrigation. The average water-use of the "crop-irrigation method combinations" derived from the monitored fields was extrapolated to the respective share of all mapped fields. The total agricultural water-use was computed by adding up these volumes:

$$TWU = \sum_i \overline{WU}_i \times A_i \qquad \text{(Formula 1)}$$

where:

TWU	=	Total water-use (m^3)
$\overline{WU}_i$	=	Average water-use of crop-irrigation method combination i (m^3/ha)
A_i	=	Total irrigated area of crop-irrigation method combination i (ha)
i	=	Index for crop-irrigation method (e.g. barley-sprinkler)

Reference Evapotranspiration (ET_0) was computed using the FAO Penman-Monteith equation from climatic data of an automatic weather station located in the middle of the valley and crop evapotranspiration (ETcrop) was determined by defining growth stages and crop factors (ALLEN et al., 1998). According to DASTANE (1978), ineffective rainfall is that portion of rainfall which is lost by surface run-off, unnecessary deep percolation losses and the moisture remaining in the soil after the harvest of the crop, which is not useful for next season's crop. Owing to deep homogeneous soils, high infiltration rates, flat topography in the irrigation area and dry soil conditions at harvest, all rainfall was assumed effective. The net irrigation requirement was defined as the difference between the crop water requirements and effective rainfall. Water-use efficiencies (OWEIS and ZHANG, 1998) for rainfall, total water, and irrigation water were determined as follows:

$$WUE_{rf} = \frac{Y_{rf}}{R} \qquad \text{(Formula 2)}$$

$$WUE_{tot} = \frac{Y_{ir}}{WU + R} \qquad \text{(Formula 3)}$$

$$WUE_{ir} = \frac{Y_{ir} - Y_{rf}}{WU} \qquad \text{(Formula 4)}$$

where:

R	=	rainfall during crop growing period (m³/ha)
Y	=	yield (kg/ha)
WU	=	water-use (m³/ha)
WUE	=	water-use efficiency (kg/m³)
ir	=	irrigated
rf	=	rainfed

3. Results

The 2002/03 rainfall was above average: 298 mm. The first rain occurred in October 2002 and the last major rainfall event in March 2003. After that, only small occasional events were recorded until May. Average planting dates for irrigated crops were October 29 (barley), November 26 (wheat), and December 31 (cumin). The average harvesting dates were May 15 (barley and cumin), and May 26 (wheat). Crop water

requirements during the growing season were determined as 372 mm for barley, 259 mm for cumin and 390 mm for wheat. The EC of the groundwater was generally high, ranging from 2.3 to 16.8 dS/m. The highest groundwater EC used for sprinkler-irrigated crops was 14.2 dS/m (barley), 7.9 dS/m (cumin) and 11.4 dS/m (wheat). On average, the EC of groundwater used for sprinkler irrigation was 38.5% lower (barley) and 42% lower (wheat) compared to surface irrigation (Fig. 2).

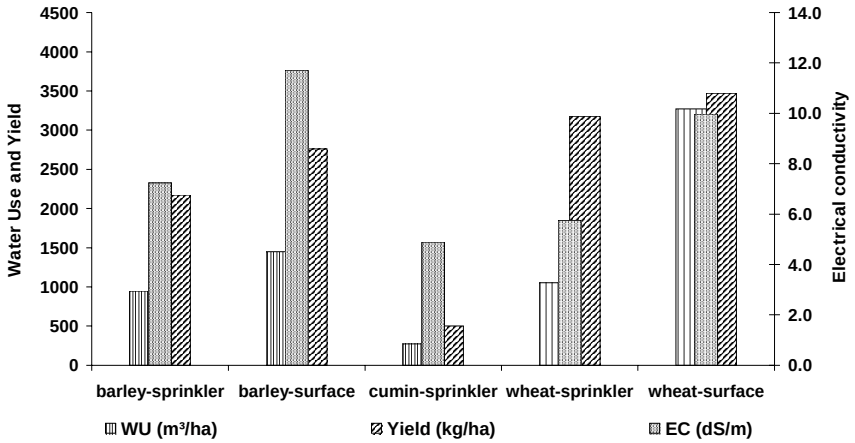

Figure 2:
Water-use, yield and electrical conductivity for combinations of crops and irrigation methods

Sprinkler-irrigated barley yields were 21% lower than surface-irrigated yields, whereas sprinkler-irrigated wheat yields were only 8% lower than surface-irrigated yields. In contrast to barley, which received 100% more nitrogen on surface-irrigated fields, nitrogen applications to wheat were equally high for sprinker irrigation and surface irrigation (Table 1). Wheat had the largest net irrigation requirement (122 mm), followed by barley (88 mm) and cumin (31 mm). Compared to net irrigation requirements, the monitored farmers applied on average 1.1 times the amount of water (949 m³/ha) to sprinkler-irrigated barley, 1.6 times (1447 m³/ha) to surface-irrigated barley, 0.9 times (273 m³/ha) to cumin, 0.9 times (1053 m³/ha) to sprinkler-irrigated wheat, and 2.7 times (3270 m³/ha) to surface-irrigated wheat (Table 2).

The monitored area accounted for 20.5% of the total irrigated area (Fig. 3) of which 73% was irrigated by sprinkler irrigation and 27% by surface irrigation (Table 3). Total ground water abstractions for winter crops in the valley were found to be about 636,000 m³, equal to 2.6 mm over the area of the two watersheds or 1.25% of the

annual average rainfall. This volume was applied to surface irrigated wheat (48.4%), sprinkler-irrigated wheat (29.5%), sprinkler-irrigated barley (12.7%), surface-irrigated barley (6.4%), and sprinkler-irrigated cumin (3.0%).

Table 1:
Sample size and average agronomic parameters

	barley-sprinkler	barley-surface	barley-rainfed	cumin-sprinkler	cumin-rainfed	wheat-sprinkler	wheat-surface	wheat-rainfed
No. of monitored fields	9	5	12	5	4	12	7	11
Monitored area	26.8	6.8	71.7	7.8	22.5	37.5	14.6	39.2
Dominant Variety	Arabi aswad	Arabi aswad	Arabi aswad	Local	Local	Cham 6	Cham 6	Cham 6
Planting date	01/11/02	28/10/02	25/11/02	31/12/02	30/12/02	26/11/02	26/11/02	21/11/02
Harvesting date	16/05/03	14/05/03	15/05/03	15/05/03	17/05/03	26/05/03	26/05/03	27/05/03
Growing period (days)	196	198	171	135	138	181	181	187
Seed rate (kg/ha)	237	310	146	37	34	241	321	153
P-Fertilizer (kg/ha)	67	130	12	90	64	106	143	55
N-Fertilizer (kg/ha)	39	80	39	20	11	98	100	52
Yield (kg/ha)	2174	2762	1959	500	471	3175	3472	1856

Table 2:
Electrical conductivity and water-use parameters

	Barley-sprinkler	Barley-surface	Cumin-sprinkler	Wheat-sprinkler	Wheat-surface
EC of irrigation water (dS/m)	7.2	11.7	4.9	5.8	10.0
EC values (min - max)	3.3-14.2	8.4-16.8	2.5-7.9	2.3-11.4	3.3-14.2
Crop water requirements (mm)	372	372	259	390	390
Effective rain (mm)	284	284	228	268	268
Net irrigation requirement (mm)	88	88	31	122	122
Water-use (mm)	94.9	144.7	27.3	105.3	327.0
Water-use / irrigation requirement	1.1	1.6	0.9	0.9	2.7
WUE_{rf} (kg/m³)	0.7	0.7	0.2	0.7	0.7
WUE_{tot} (kg/m³)	0.6	0.7	0.2	0.9	0.6
WUE_{ir} (kg/m³)	0.2	0.6	0.1	1.2	0.5

Table 3:
Irrigated areas and groundwater abstractions in Khanasser Valley

Crop-irrigation method combination	Irrigated area		Groundwater abstractions	
	(ha)	(%)	(m^3)	(%)
Barley-sprinkler	85.3	18.7	80,960	12.7
Barley-surface	28.1	6.2	40,656	6.4
Cumin-sprinkler	69.1	15.2	18,834	3.0
Wheat-sprinkler	178.5	39.2	188,041	29.5
Wheat-surface	94.1	20.7	307,723	48.4
Total	455.1	100.0	636,215	100.0

4. Discussion

Wheat accounted for 78% of the water applied to winter crops in Khanasser Valley. Two thirds of the irrigated wheat was produced with sprinkler irrigation using only 40 percent of the water applied with both methods. Despite the higher productivity of sprinkler irrigation, farmers who had wells with a high EC (average: 10 dS/m) were using surface irrigation, because the crop is more sensitive to salinity than barley. Toxicity effects resulting from foliar application of saline water are exacerbated by strong winds and low air humidity (AYERS and WESTCOT, 1985), which are typical of the spring season in Khanasser Valley.

Some farmers changed to sprinkler irrigation despite having high salinity irrigation water. They usually avoid toxicity effects by not applying water at sensitive growth stages. Farmers prefer sprinkler irrigation for economic reasons: Harvesting costs are three times higher for surface irrigation, because combine harvesters need more time to harvest a ridged field; additional tractor passages are needed for soil preparation; higher seed rates, more fertilizer and more fuel are required. On the other hand, this is compensated by the investment costs for sprinkler systems.

The grain yield of irrigated barley was affected by controlled grazing, a land use practice with a comparatively high gross margin in northern Syria (MÄRZ, 1990). Compared to crop water requirements, barley receives more water by sprinkler irrigation than wheat. This water is applied mostly to enhance the vegetative development of barley. Farmers stop the grazing after tillering stage. Cumin appears to be more sensitive to sprinkler irrigation with high salinity water than wheat. However, small quantities of moderately saline water, applied before flowering, can help secure yields in low rainfall years.

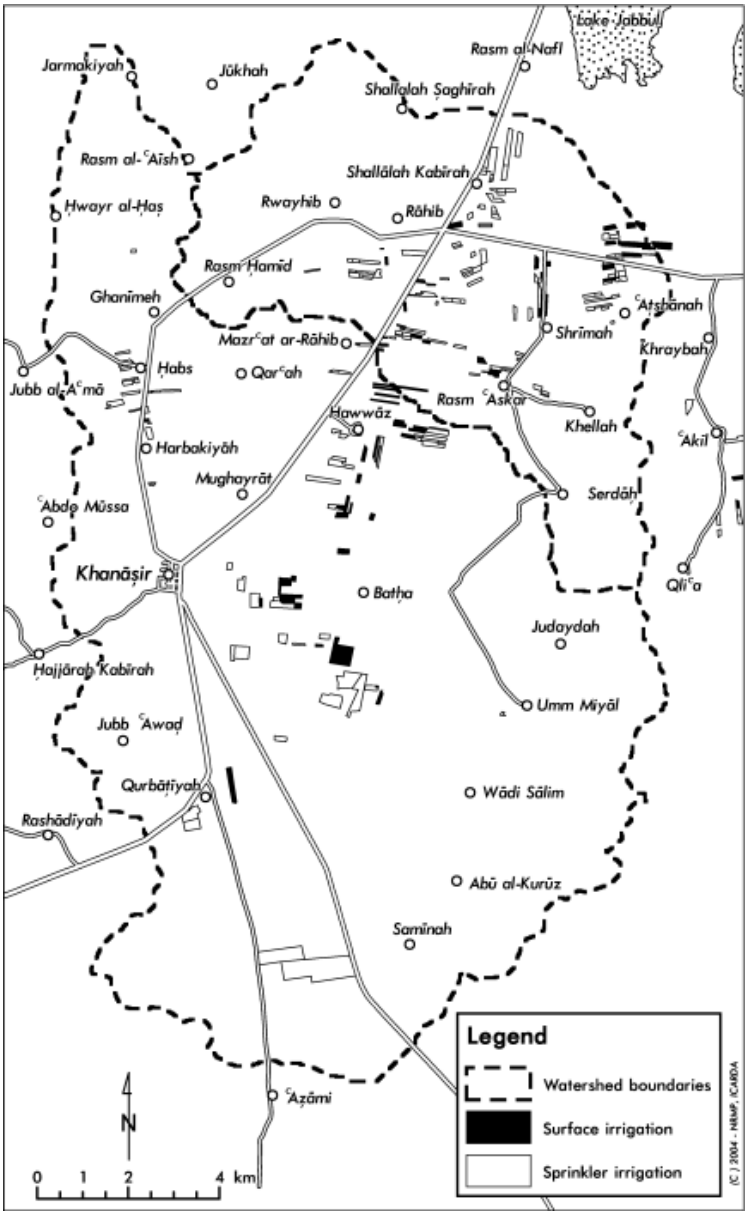

Figure 3:
Khanasser Valley, 2002-03 croping season: Fields irrigated by sprinkler irrigation and surface irrigation

Supplemental irrigation is defined as the application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth, to increase and stabilize yield (OWEIS et al., 1999). In the 2002/03 season, a majority of farmers used sprinkler technology for supplemental irrigation of wheat. On average, these farmers were applying irrigation water quite efficiently. In the individual case, however, the applied quantities were sometimes above and sometimes well below the net irrigation requirement, which indicated some potential for improvement. However, in those cases where water applications were strictly limited by well yields, water-use efficiency could hardly have been improved much, as farmers were already using deficit irrigation (ENGLISH and RAJA, 1996), i.e. applying less water then necessary to exploit the full yield potential of the crop.

In the 2002/03 season, winter irrigation in Khanasser Valley accounted for an equivalent water use of about 0.64 million m^3. A higher degree of groundwater use can be expected for an average rainfall year. Although supplemental irrigation in the rainy season represents the major share of total water abstractions in the valley, summer irrigation and domestic water use are not negligible and need to be also evaluated.

5. Conclusions

Based on the extrapolation of results from the monitored area, farmers in the Khanasser Valley applied on average about 33% more water than the net irrigation requirement. Considering that application efficiencies or leaching requirements were not taken into account, in general, farmers seem to have applied water efficiently.

In view of the scarcity of water resources in the study area, this result is quite encouraging. However, the water use study also highlighted areas of concern and topics for participatory research, such as salinity management and water use economy.

The use of saline water for leaching is problematic. On the one hand, farmers can remove temporary peaks of soil salinity by applying extra water for leaching, on the other hand, yet more salts are added to the soil profile, which can only be removed by substantial rainfall. Ways of how to optimise leaching shall be discussed with farmers in the context of participatory experiments.

Less water is required for achieving the maximum income than for achieving the optimum yield, particularly since water is more limited than land. This topic will be addressed in trials with farmers who are using sprinkler irrigation. The target will be to get a higher income from irrigation with less water.

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References

Allen, R., L. Pereira, L., D. Raes and M. Smith, 1998: Crop evapotranspiration. Guidelines for computing crop water requirements. - FAO Irrigation and Drainage Paper 56. FAO, Rome, Italy

Ayers R. S. and D. W. Westcot, 1985: Water Quality for Agriculture. - FAO Irrigation and Drainage Paper 29 Rev.1. FAO, Rome, Italy.

Bruggeman, A., 2004: Long-term computations based on meteorological observations by ICARDA and GRUZGIPROVODKHOZ, 1982, unpublished.

Dastane, N. G, 1978: Effective rainfall in irrigated agriculture. - FAO Irrigation and Drainage Paper No. 25. FAO, Rome.

Deckers, J. A., F. O. Nachtergaele, and O. C. Spaargaren, 1998: World Reference Base for Soil Resources: Introduction. - First Edition, International Society of Soil Science (ISSS), International Soil Reference and Information Center (ISRIC) & Food and Agriculture Organization of the United Nations (FAO). Acco, Leuven, Belgium.

De Pauw, E., 2003: How similar are the CWANA and northern Mediterranean regions to Khanassir? - Technical Note. Agroecological Characterization Project, Natural Resources Management Program, ICARDA.

Diekmann, J., 2003: Monthly groundwater monitoring of Station Operations Dept. - ICARDA, Aleppo, Syria.

English M. and S. N. Raja, 1996: Perspectives on deficit irrigation. - Ag. Water Man. 32 (1): 1-14.

GRUZGIPROVODKHOZ, 1982: Hydrogeological and hydrological surveys and investigations in four areas of the Syrian Arab Republic: Summary report. - Volume I. Hydrology. Book 1. Text. Tiblis 1982.

Kasmo, B., 1997: Reclamation of salt-affected soils, using a field monolith, in Al-Matekh Region, south of Aleppo. - Thesis submitted to the Department of Soil and Soil Reclamation, Faculty of Agriculture, Aleppo University, in fulfillment of the Degree of Master of Agricultural Engineering, Aleppo, Syria (in arabic).

LOUIS BERGER INTERNATIONAL, 1982: Reconnaissance Soil Survey. - Louis Berger International, Inc., Remote Sensing Institute, South Dakota University, United States Agency for International Development and the Syrian Arab Republic. Land Classification/Soil Survey Project of the Syrian Arab Republic, Volume 2, 1: 500,000 scale. Contract AID/NE-C-1644.

MAAR (Ministry of Agriculture and Agrarian Reform), 1999: The annual agricultural statistical abstract. - Department of Planning and Statistics, Division of Agricultural Statistics. Damascus, Syria.

März, U.,1990: Farm classification and impact analysis of mixed farming systems in northern Syria. - Farming Systems and Resource Economics in the Tropics 7. Hohenheim, Univ., Diss., 1989, Wiss.-Verl. Vauk, Kiel.

Mikhailov, I. Y., V. P. Ponikarow, and A. Troizky, 1966: The geological map of Syria. - Explanatory notes. Sheet I-37-XX (Salamiyeh). [Prepared by Technoexport for the Ministry of Industry S.A.R., Department of Geological and Mineral Research.]

Oweis, T. and H. Zhang, 1998: Water-use efficiency: Index for optimizing supplemental irrigation of wheat in water scarce areas. – Journal of Applied Irrigation Science 2, 321 – 336.

Oweis, T., A. Hachum, and J. Kijne, 1999: Water harvesting and supplemental irrigation for improved water use efficiency in dry areas. - SWIM Paper 7. : International Water Management Institute, Colombo, Sri Lanka

Schweers, W., A. Bruggeman, A. Rieser, B. Abu-Zhakem, J. Asfahani, N. Kadkoy, and B. Kasmo, 2003: Assessment of groundwater resources for sustainable management in the Khanasser Valley, northwest Syria. - ACSAD/BGR Workshop on Soil and Groundwater Quality: Monitoring, Management and Protection, 23 – 25 June 2002, Amman, Jordan.

Wilde, E., 1998: Variability of the Soil Permeability in the Khanasser Valley, Syria due to Soil and Land Management Practices. - Project work. Institut für Wasserwirtschaft und Kulturtechnik. Universität Karlsruhe (TH).

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