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Title:

Changes in Water Management and Irrigated Agriculture In the *Lower Jordan River Basin in Jordan*

A technical Review of Irrigated Farming Systems Present Situation & Impacts of the Water Management Changes in Prospect

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"On the one hand, the fundamental fear of food shortages encourages ever greater use of
water resources for agriculture.
On the other, there is a need to divert water from irrigated food production
to other users and to protect the resource and the ecosystem.
Many believe this conflict is one of the most critical
problems to be tackled in the
early 21st century."

The Global Water Partnership Framework for
Action to achieve the Vision in the 21st Century

ACKNOWLEDGMENT

The acknowledgments are the sole section where the report's author can let his imagination guides his words, elsewhere the scientific reason is the strongest. Between classic remarks and winks, some lines will be written here. Firstly I would like to particularly thank my two supervisors. The first one shared the office with a *brilliant intern* during one year and despite his tendency to always have new ideas and new points to study supported me and helped me a lot during my two stays in Jordan: M.Rémy Courcier, head of this pleasant *Regional Mission for Water and Agriculture (MREA)*. The other one was more distant since he is working in Colombo: M.François Molle from the *International Water Management Institute (IWMI).* The few exchanges we had and notably the two *'brainstorming'* realized in Amman have been very productive. I learned a lot with them and it was the pleasure to see two old friends discussing about Brazil and Water…

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A page is turned; I welcome you all in Hyderabad to learn to know India…

This text commits only me and not the French Embassy in Jordan, I sincerely thanks for its support

FOREWORD

This work is the fruit of two stays realized in Jordan during the years 2003 and 2004. These interns have been done within the framework of one cooperation between the *Regional Mission for Water and Agriculture* (MREA) and the *Comprehensive Assessment of Water Management in Agriculture*, a research program developed by the *International Water Management Institute* (IWMI, Colombo), lasting since two years and aiming to create a multidisciplinary analysis of water management inside the *Lower Jordan river Basin in Jordan.*

The knowledge and the global understanding of the processes occurring within the Lower Jordan River Basin have been made possible thanks to this long-drawn-out job which results in the present report. Within this research project, our task was to study the irrigated farming systems in their agronomical, economical and social components in order to understand the actual observed dynamics and to identify the evolutions to be recorded as far as irrigated agriculture is concerned.

Some parts of this assessment will then be gathered with other studies lead within the same framework and a comprehensive synthesis presenting the historical development of the Lower Jordan River Basin in Jordan in relation with the evolution of water management in what become one of the most water scarce context in the world will be written in the following year.

SUMMARY & KEY WORDS

Key Words: Jordan, water management, political measures, impact assessment, *Lower Jordan River Basin in Jordan*, irrigated agriculture, geographical zoning, farming system, farmer, typological classification

Jordan and in particular the *Lower Jordan River Basin in Jordan*, which is the most dynamic region within the country since it gathers the majority of the industries, 83 % of the population and 80% of the irrigated surfaces, supplying in addition 80% of the water resources of the country knows an important shortage of water. This is the result of a generalized economic development lasting since fifty years and which has required a global reclamation of the rare water resources of the *basin* in order to meet the increasing needs of a growing population with always higher living's standards. All the surface waters are now controlled and used -or will soon be reclaimed; renewable aquifers are overexploited at 180 % of their sustainable rate, while fossil aquifers are already pumped. The only solution to meet the future needs of the population will be the implementation of huge projects at very high costs.

Since 1995 and the official recognition of the Jordanian *water crisis*, the priority is to meet the domestic, tourist and industrial needs. The agricultural sector still representing 70 % of the total uses in Jordan bore, still bears and will have to bear some water restrictions. These restrictions have not been, until yet, a curb on the development of the irrigated agriculture. However new changes in water management will soon occur. The irrigated agriculture in the *Lower Jordan River Basin* is organized around two large agricultural regions: on one hand, the Jordan Valley where a very intensive agriculture allowing producing fruits and vegetables in winter has been developed since the 1960 thanks to very small farms (3,5 to 10 hectares), on the other hand the eastern plateaux called *Highlands* where large farms (25 hectares on average) allow, since the 1980s, a summer production of fruits and vegetables. A large diversity of farming systems more or less intensive, more or less profitable can be described in these two areas both for the fruits and the vegetables production. However four main groups of *'farmers'* can be identified: the large land investors or absentee owners developing mainly very extensive orchards of citrus or olive trees, the large entrepreneurs-farmers implementing very intensive, profitable and costly systems (greenhouses and stone fruit trees orchards), the familial farmers very diverse (vegetables under greenhouses or in open field, citrus, stone fruit, bananas orchards…) and finally the poor farmers developing extensive systems of vegetables in open field. These farmers will not be affected in the same way by the changes in agricultural water management to come (increase in water prices, shift from freshwater to treated waste water) and aiming at reducing the agricultural use of freshwater. The high-value fruits and vegetables production developed for the local and the export market by the large entrepreneurs-farmers will not be affected by the measures which could even accentuate the process of intensification now running. The familial farming systems will be slightly affected, but could adapt themselves to the new conditions in order to continue to supply the important local market. On the contrary, the poor farmers will not be able to bear the changes to come and will disappear. That will raise a set of social problems the government will have to face by developing some attendant measures in particular in terms of agricultural supervision and advising. The case of the large land investors is delicate since some of them will see the already low profitability of their farm strongly decrease while others will not be affected by the measures. The history of changes in water management in Jordan actually highlights the socio-political blockings within the Jordanian Society the government has to face to reach a more sustainable water-resources-exploitation. Some farmers with strong support in the parliament and mainly land investors and/or ancient Jordanian-Bedouins belonging to large influent tribes actually slow down the measures to be taken and soften the impact they could have on their extensive farming system. This mainly leads to the persistence of ancient water rights explaining some of the main agricultural aberrations in the Jordanian agricultural landscape as the very profitable and water-consuming bananas farms in the Jordan Valley and the non profitable irrigated olives trees orchards in the Eastern desert.

The Jordanian agricultural landscape will not be strongly affected by the water management changes to come and if some reallocations of freshwater could be possible, deeper modifications are necessary to meet the growing needs of the population. This would only be possible by the strengthening of the envisaged measures or by the implementation of others rules aiming at a reorientation of the Jordanian agriculture notably towards a drastic decrease of the non profitable irrigated surfaces of olive trees in the eastern desert and of the bananas surfaces which could be replaced by date palm trees very profitable too and less water-consuming.

Mots Clés : Jordanie, gestion de l'eau, mesures politiques, impact, *bassin versant du Jourdain en Jordanie*, agriculture irriguée, zonage géographique, système d'exploitation, exploitant agricole, typologie.

La Jordanie et plus particulièrement le *bassin versant du Jourdain en Jordanie* constituant la région la plus dynamique du pays car regroupant près de 83 % de la population, 80 % des surfaces irriguées, la majorité des industries et approvisionnant la nation avec près de 80% de ces ressources hydriques connaît aujourd'hui une situation d'extrême pénurie en eau. La situation actuelle, préoccupante, est le résultat d'un développement économique généralisé durant les dernières cinquante années qui a nécessité une mobilisation toujours croissante des rares ressources en eau afin de subvenir aux besoins d'une population grandissante au niveau de vie toujours croissant. Les eaux de surfaces sont ainsi d'ores et déjà toutes contrôlées et utilisées -ou du moins en voie d'exploitation ; les nappes souterraines renouvelables sont, de plus, surexploitées à près de 180 % de leur recharge annuelle alors que des prélèvements sont également effectuées dans les aquifères fossiles du sud du pays. Seuls des projets pharaoniques pourront permettre dans le futur de subvenir aux besoins en eau potable des populations. Le projet de canal reliant la mer rouge à la mer morte afin de produire de l'eau dessalée pour approvisionner en eau potable les grandes villes de la région est l'exemple même de cette fuite en avant, malgré tout nécessaire, se faisant à des coûts toujours croissants.

En Jordanie, l'agriculture représente aujourd'hui 70 % des usages de l'eau. Hors, depuis 1995 et la reconnaissance officielle de la crise de l'eau jordanienne, le gouvernement a fait des usages domestiques, touristiques et industriels sa priorité. L'agriculture et notamment l'agriculture irriguée dans le *bassin versant du Jourdain en Jordanie* a déjà connu, connaît et connaîtra donc encore des restrictions d'usage en eau. Ceux-ci n'ont, pour l'instant, pas constitué un frein à son développement. Au sein de ce bassin versant, cette agriculture, duale, s'organise principalement autour de deux régions complémentaires. D'un côté la vallée du Jourdain où l'on trouve essentiellement, et ce depuis les années 1960, de petites exploitations très intensives (3,5 à 10 hectares) permettant une production légumière et fruitière hivernale ; de l'autre les *Highlands*, plateaux s'étendant vers l'est du pays où se sont développées, principalement depuis les années 1980, de plus grandes exploitations (25 hectares en moyenne) produisant fruits et légumes durant l'été. Au sein de ces deux zones, on peut décrire une grande diversité de système de production plus ou moins intensif, plus ou moins rentable tant en ce qui concerne la production légumière que fruitière. D'un autre coté, une typologie simple des exploitants agricoles peut être effectuée. L'on distingue en effet quatre grands groupes d'exploitants : les grands investisseurs fonciers ou propriétaires absentéistes développant des systèmes de production extensifs (le plus souvent des vergers d'oliviers ou de citrus) ; les grands entrepreneurs agricoles mettant en place des systèmes intensifs très rentables mais lourds en investissements (légumes sous serre et vergers de fruits à noyaux) ; les exploitants familiaux parmi lesquels on peut trouver une grande diversité de systèmes de production (légumes sous serre ou en plein champ, vergers de citrus, fruits à noyaux, bananes…) et enfin les agriculteurs pauvres développant des systèmes extensif de légumes en plein champ.

Ces différents exploitants ne seront donc pas affectés de la même façon par les nouvelles mesures de gestion de l'eau mises en place (taxation des pompages privés au-delà d'un certain volume limite fixé) ou à venir dans un futur proche (augmentation des prix de l'eau agricole 'publique' dans la vallée du Jourdain et remplacement de l'eau fraîche par de l'eau usée retraitée dans le nord de cette zone comme cela a été le cas dans le sud de la vallée au cours de la précédente décennie) et visant à la réduction de l'utilisation agricole des eaux de bonne qualité. La production légumière et fruitière à haute valeur ajoutée, permettant l'approvisionnement du marché local ainsi que l'exportation d'importants surplus, développée dans le *bassin versant jordanien du Jourdain* par de grands agriculteurs-entrepreneurs ne devrait pas être affectée par ces mesures. Ces dernières pourraient même accentuer les processus d'évolution qui sont déjà en cours aujourd'hui et qui relèvent principalement d'une intensification du paysage agricole jordanien. Les systèmes familiaux, s'ils verront leur rentabilité baisser de quelques pourcents, devraient pouvoir s'adapter relativement rapidement aux conditions à venir et ainsi continuer d'approvisionner l'important marché local. Au contraire, les agriculteurs pauvres ne pourront pas supporter les changements à venir et sont amenés à disparaître ce qui posera de nombreux problèmes sociaux auxquels le gouvernement devra faire face notamment en développant des mesures d'accompagnement en terme d'encadrement et de conseil agricole. Le cas des grands investisseurs fonciers est plus délicat à traiter. En effet, si certains verront la déjà faible rentabilité de leur exploitation fortement baisser, d'autres au contraire ne devraient pas être affectés par les mesures à venir. L'histoire des changements enregistrés dans la gestion de l'eau en Jordanie fait en effet apparaître les nombreux blocages socio-politiques, internes à la société jordanienne, auxquels se trouve confronté le gouvernement dans sa volonté d'atteindre une situation plus durable de l'exploitation de ses rares ressources en eau. Certains agriculteurs, développant des systèmes parmi les plus extensifs et les moins rentables, et notamment les grands investisseurs fonciers et les anciens bédouins jordaniens reconvertis dans l'agriculture, jouent en effet de leur soutien auprès du parlement afin de ralentir la mise en place des mesures gouvernementales ou tout du moins d'en atténuer les impacts sur leurs systèmes de production. Cela résulte en la persistance d'anciens droits et notamment de droits d'eau acquis par le passé permettant de développer et de maintenir des activités aberrantes dans le contexte jordanien. L'on peut citer ainsi la culture de bananes, très rentable mais très consommatrice en eau, dans la vallée du Jourdain et les vergers d'oliviers irrigués non rentables consommant une eau potable dans les déserts de l'est du pays.

Les mesures de gestion de l'eau agricole récemment prises et à venir prochainement n'entraîneront donc pas, dans leur état actuel, de grandes modifications du paysage agricole jordanien, seules les dynamiques actuelles seront accentuées. A l'image de l'utilisation des eaux usées traitées dans le nord de la vallée, ces mesures peuvent permettre de réallouer une petite quantité d'eau à un usage domestique sans menacer l'avenir de l'agriculture productive jordanienne cependant de plus profondes modifications sont nécessaires afin de diminuer de façon notable la consommation agricole des eaux fraîches en Jordanie et d'atténuer ainsi la surexploitation actuelle des ressources renouvelables qui mène à une coûteuse fuite en avant nécessaire afin de subvenir aux besoins d'une population croissante. Cela ne pourra être fait que par une amplification des mesures considérées ici et/ou par la mise en place d'autres mesures visant à réorienter l'agriculture jordanienne notamment en réduisant drastiquement les surfaces non rentables de vergers d'oliviers irrigués dans les déserts et les surfaces de bananiers qui pourraient alors être remplacées par des dattiers tout aussi rentables et moins consommateur d'eau.

Table of Contents

ACKNOWLEDGMENT 3
FOREWORD 4
SUMMARY & KEY WORDS 5
I. INTRODUCTION 13
II. A NON SUSTAINABLE EXPLOITATION OF THE WATER RESOURCES 15
II.1 FOREWORD 15
II.2 CHARACTERISTICS OF THE LOWER JORDAN RIVER IN JORDAN 15
II.2.1 General presentation 15
II.2.2 Morphologic Characteristics 17
II.2.3 Hydrological description 17
II.3 SOME WORDS ON HISTORY: A RAPID DEVELOPMENT 19
II.3.1 The Situation in 1950: The pre-exploitation phase 19
II.3.2 The situation in the mid 1970s: the exploitation phase 21
II.4 THE SITUATION IN 2000 22
II.4.1 Historical Context 22
II.4.2 Unsustainable exploitation and reorientation of the water management policies 23
II.4.3 Present water balance 25
II.5 CONSEQUENCES 27
II.5.1 A headlong rush into more expensive water resources, some pharaonic projects 27
II.5.2 Environmental degradation 31
II.5.3 Questions rose up by the irrigated agriculture. 37
III. LESSONS FROM SURVEYS-Agro-economic diagnosis- 39
Part 1: Agricultural Zoning 39
III.1 PROBLEMS RAISED UP BY AN EVALUATION OF THE IRRIGATED SURFACES 39
III.1.1 Introduction: different sources of information 39
III.1.2 Presentation of the results 39
III.2 DISCREPANCY BETWEEN SEVERAL EVALUATIONS OF THE AGRICULTURAL GROUNDWATER ABSTRACTION 42
III.2.1 Mode of evaluation 42
III.2.2 Results 45
III.3 AGRICULTURAL ZONING 47
III.3.1 General mapping 47
III.3.2 The Jordan Valley 49
III.3.3 The Highlands 60
IV. LESSONS FROM SURVEYS-Agro-economic diagnosis- 66
Part 2: An experimental classification of farming systems and farmer's strategies.... 66
IV.1 FOREWORD 66
IV.2 THE FARMING SYSTEM CONCEPT & AIMS OF THE STUDY 66
IV.2.1 Foreword 66
IV.2.2 The Farming System Notion 66
IV.2.3 Aims of the Study 69
IV.3 METHODOLOGY OF THE AGRO-ECONOMIC DIAGNOSIS 69
IV.3.1 Introduction 69
IV.3.2 Graphical representation 70
IV.4 AGRO-ECONOMIC DESCRIPTION OF THE FARMING SYSTEMS 73
IV.4.1 General Cropping pattern 73
IV.4.2 Farming systems of the Jordan Valley 73
IV.4.3 'Groundwater Farming Systems' of the Highlands 93
IV.4.4 'Surface water farming systems' in the Highlands 107
IV.4.5 Irrigated Olive Trees 112
IV.5 SYNTHESIS: FARMERS' CHARACTERIZATION AND STRATEGIES DEVELOPPED 120
IV.5.1 A 'socio-economic characterization' of the farmers 120
IV.5.2 Strategies developed by each kind of farmers 127
IV.5.3 Summary table: farmer's strategies. 128
V. WATER MANAGEMENT CHANGES' IMPACTS ON THE FARMING SYSTEMS PROFITABILITY 133

V.1 FOREWORD ON THE METHODOLOGY USED 133
V.2 CHANGES IDENTIFIED IN WATER MANAGEMENT 134
V.2.1 Introduction 134
V.2.2 Water price increase 134
V.2.3 Shift from Freshwater to treated waste water 139
V.3 IMPACTS OF THE CHANGES IN MANAGEMENT ON FARMERS' REVENUE 145
V.3.1 Foreword 145
V.3.2 Increase of public water prices in the Jordan Valley 145
V.3.3 Shift from freshwater to treated waste water in the north of the valley 149
V.3.4 Conclusion on the Jordan Valley 151
V.3.5 Increase of Prices in the Highlands: Impact of the urban pressure 151
V.3.6 Increase of prices in the Highlands: Impact of the By-Law No.85 of 2002 152
V.3.7 Current and future evolutions to be recorded 156
VI. SCALING UP TO THE RIVER BASIN SCALE 167
VI.1 INTRODUCTION: ITEMS CONSIDERED WITHIN THE ASSESSMENT 167
VI.2 THE NEW ECONOMICS RULES 167
VI.2.1 Impact of the quotas' suspension on the River Basin Scale 168
VI.3 THE SHIFT FROM FRESH TO TREATED WASTER WATER IN THE NORTH OF THE JORDAN VALLEY 171
VI.3.1 Agricultural losses in production and value 171
VI.3.2 Freshwater mobilization and 'reallocation' 173
VI.4 INCREASE OF WATER COST: A SOURCE OF REVENUE FOR THE GOVERNMENT 174
VI.5 A SHIFT TO A HOMOGENIZED ALLOCATION OF WATER FOR ALL KIND OF CROPS 175
VI.6 GROUNDWATER CONTROL IN THE JORDAN VALLEY BASIN 177
VI.7 EVOLUTION IN PROSPECT IN THE HIGHLANDS 177
VI.7.1 A need for water quality conservation 177
VI.7.2 Digging up of irrigated olive trees 180
VI.7.3 Implementation of the groundwater By-Law No.85 of 2002 181
VI.7.4 Suppression of fruits and vegetables exports 183
VI.7.5 Buy Out of wells 183
VI.7.6 Use of treated waste water in the Highlands 185
VI.7.7 Irrigation Advisory Services (IAS) and On-Farm Management 185
VI.8 SUMMARY: 'GAIN AND LOSSES' OF TWO SCENARIOS 186
VI.8.1 Two Scenarios 186
VI.8.2 Expected impacts: costs and benefits analysis 186
VII. CONCLUSION 192
BIBLIOGRAPHY 195
APPENDIXES 212

Table of Tables

Table 1. Summary table of the water resources and use in Jordan and in the Lower Jordan River Basin in Jordan 26
Table 2. Number of operating wells controlled by the Water Authority of Jordan in 1995-2002 27
Table 3. Approximate costs of several water supply projects 29
Table 4. Irrigated Surfaces within the Lower Jordan River Basin in Jordan..... 40
Table 5. Several evaluations of the irrigated surfaces in the Amman-Zarqa Basin 42
Table 6. Irrigated areas of the Amman-Zarqa and the Yarmouk Groundwater Basins according to the agricultural zoning..... 44
Table 7. Different Scenario of Water consumption according to the agricultural areas 44
Table 8. Different ways to evaluate the agricultural water abstraction in the Amman-Zarqa and the Yarmouk groundwater Basins 45
Table 9. Repartition of the Irrigated Areas in the Highlands of the Lower Jordan River Basin in Jordan 60
Table 10. Structural aspects of agricultural credit in Jordan -loans contracted in 1999- 72
Table 11. Yield and market prices observed 75
Table 12. Yield and market prices of the main vegetables cropped in the valley 77
Table 13. Net Return ($/dunum) in Greenhouses farms in the Jordan Valley 84
Table 14. Yield and market prices of the main vegetables cropped in open field in the Highlands 97
Table 15. Net return ($/dunum) in Open Field farms in the Highlands 98
Table 16. Yield and prices in ‘greenhouses farming systems’ in the Highlands..... 102
Table 17. Cropping pattern in greenhouses farms in the Highlands 102
Table 18. Net return ($/dunum) in greenhouses farms in the Highlands 103
Table 19. Typical Cropping pattern of the fruit trees farms in the Highlands..... 105
Table 20. Yield and Prices observed in Fruit trees farm in the eastern desert 106
Table 21. Net Return ($/dunum) in Fruit Trees Farm in the Highlands..... 106
Table 22. Net Return ($/dunum) in open field farms along the Side Wadis 109
Table 23. Yield and Prices in Fruit trees farms and mixed farms in the Uplands..... 112
Table 24. Typical vegetables cropping sequence in mixed farms in the Uplands..... 112
Table 25. Net Return ($/dunum) in fruit trees farms along the Side Wadis..... 112
Table 26. Main characteristics of the Olive Trees Plots within the Lower Jordan River Basin in Jordan 114
Table 27. Evolution in olive trees surface and olive production in Jordan 117
Table 28. Strategies developed by the different kinds of farmers within the Lower Jordan River Basin in Jordan 130
Table 29. Effective water prices ($/m3) for each kind of farmers in the Lower Jordan River Basin in Jordan 131
Table 30. Public Water Prices in the Jordan Valley..... 135
Table 31. Rules of water allocation in the Jordan valley..... 135
Table 32. Water prices according to the Volume abstracted in agricultural wells as it is mentioned in the By-Law No.(85) of 2002 137
Table 33. New rules concerning a taxation of water abstracted from Brackish Aquifers..... 137
Table 34. Jordanian Guidelines for Reuse of Treated Domestic Wastewater..... 140
Table 35. Yield potential of selected crops as influenced by irrigation water salinity (ECw) and soil salinity in the rootzone (ECe)..... 144
Table 36.Equations of yields (in % of yield potential) in function of the water salinity (Ecw)..... 144
Table 37. Yield potential for three given levels of water salinity for the main crops grown in the Jordan Valley..... 144
Table 38. Impact of Public water Price Increase on Citrus and Bananas Farms in the Jordan Valley 147
Table 39. Impact of Public water Price Increase on vegetables Farming systems in the Jordan Valley 148
Table 40. Expected decrease in the profitability of farming systems in the north of the valley because of the shift from freshwater to treated waste water 150

Table 41. Impact of the water price increase on suburban farming systems 151
Table 42. Impact of the By-law on the revenue of farmers in different farming systems in the Highlands 153
Table 43. Impact of the By-Law on bananas farms in the south of the Jordan Valley 161
Table 44. Possible strategies developed by bananas farmers in front of the By-Law if their wells are illegal 163
Table 45. Impact of the quotas' suspension on the profitability of bananas farming systems in the Jordan Valley 169
Table 46. Consequences of a global decrease of the surfaces planted with bananas in the Jordan Valley 170
Table 47. Decrease in volume and in value to be expected with the shift to treated waste water in the north of the Jordan Valley 172
Table 48. Costs of a water quality decrease in the Highlands 178
Table 49. Total value produced by irrigated agriculture thanks to groundwater in the Highlands 180
Table 50. Global Impacts of the By-Law at the Groundwater Basin Level 182
Table 51. Costs of wells' buy out per unit of surface 184
Table 52. Water 'savings' to be expected in the scenario **'virtuous evolution'** 189

Tables of Figures and Charts

Figure 1. Limits and drainage area of the Lower Jordan River Basin in Jordan 14
Figure 2. Rainfall distribution in the Lower Jordan River Basin in Jordan 16
Figure 3. Topography of the Jordan River Basin in Jordan 16
Figure 4. Groundwater and Surface water Basins in the lower Jordan River Basin 18
Figure 5. Evolution of the number of wells in north Jordan since the 1950s 20
Figure 6. Groundwater abstraction (return flow unaccounted) by kind of use within the Jordan River Basin in Jordan (Source of the figures: MWI-database) 28
Figure 7. Example of drop in water table in aquifers of the Eastern Jordan (Amman-Zarqa Basin) 32
Figure 8. Example of the water quality deterioration in the aquifers of the Eastern Jordan (Amman-Zarqa Basin) 32
Figure 9. Evolution of the dead Sea level 36
Figure 10. Evolution of the Dead Sea's inflow 36
Figure 11. Agricultural Zoning in the Lower Jordan River Basin in Jordan 47
Figure 12. Agricultural Zoning of the Jordan Valley 50
Figure 13. Irrigation Network in the Jordan Valley 52
Figure 14. Origin of the Irrigation Water used in the middle Valley 54
Figure 15 Net Return and Economic profitability of the open field vegetables farms in the Jordan Valley 81
Figure 16. Evolution of Dates production in Jordan 92
Figure 17. Profitability of the open field vegetables farms in the Highlands 100
Figure 18. Profitability of the vegetables farms equipped with greenhouses in the Highlands 103
Figure 19. Expected evolution of Olive Production in Jordan until 2020 116
Figure 20. Evolution of Olive production in Jordan 117
Figure 21. Jordanian market of Olive tree's production since 1990 118
Figure 22. Repartition of effective water prices ($/m3) within for classes of prices according to the different kinds of farmers 131
Figure 23. Effective water prices ($/dunum) in the different farming systems within the Lower Jordan River Basin in Jordan. 132
Figure 24. Effective water prices (% of total costs) in the different farming systems within the Lower Jordan River Basin in Jordan. 132
Figure 25. Water allocation in the Jordan Valley (new rules) 136
Figure 26. Impact of the By-Law Implementation on the profitability of open field vegetables farms in the Eastern Desert 157
Figure 27. Period and Zoning of agricultural exports within Jordan (value and surface) 183

Tables of Pictures

Picture 1. Terraces on the Dead Sea Shore 36
Picture 2. The King Abdullah Canal in the middle of the Valley 51
Picture 3. A pumping station within the Jordan Valley........ 51
Picture 4. The extreme north of the valley........ 53
Picture 5. Open field landscape in the north of the Valley (Source: MREA, 2004) 54
Picture 6. General landscape of the Middle valley: A greenhouses area (Source: MREA, 2004) 56
Picture 7. “off-farm” irrigation network in the southern Jordan Valley (Source: MREA, 2003) 59
Picture 8. Bananas Landscape in the south of the valley (Source: MREA, 2003) 59
Picture 9. Diverse landscapes of the Eastern Deserts........ 62
Picture 10. General landscape of the 63
Picture 11. The Zarqa River 63
Picture 12. General landscape of the Uplands in The Lower Jordan River Basin in Jordan........ 64
Picture 13. The Suburban Area........ 65
Picture 14. The Transition Area........ 65
Picture 15. Open field farm in the northern (left) and in the southern part of the valley (right) 74
Picture 16. Greenhouses in the northern Valley (left) and in the southern valley (right)........ 83
Picture 17. Citrus plots in the north of the valley........ 86
Picture 18. Bananas farm in the south of the valley 88
Picture 19. young palm trees farm in the middle of the valley (Source: MREA, 2003) 92
Picture 20.Rented or owned farm in the Eastern Desert........ 94
Picture 21. Typical sharecropping farm in the Eastern desert (Source: MREA, 2003)........ 94
Picture 22. Typical open field farm in the suburban area (Source: MREA, 2003) 94
Picture 23. Typical open field farm in the Upper Yarmouk Area (Source: MREA, 2003)........ 94
Picture 24. A greenhouses farm in the Eastern Desert (Source: MREA, 2003)........ 101
Picture 25. Familial fruit trees farm in the Eastern Desert (Source: MREA, 2003)........ 104
Picture 26. Entrepreneur’s fruit trees farm in the Eastern Desert (Source: MREA, 2004) 105
Picture 27. Mint and Parsley farm along the Zarqa River........ 108
Picture 28. Open field farm with classic crops along a small Side Wadi........ 108
Picture 29. Greenhouses farm irrigated thanks to direct pumping in a small Side Wadis........ 108
Picture 30. Forage farm irrigated thanks to treated waste water along the Zarqa River 108
Picture 31. Characteristic irrigated olive trees farm in the Eastern Desert (Source: MREA, 2003) ... 113
Picture 32. Rainfed olive trees orchard (Source: MREA, 2002)........ 115

Tables of Boxes

Box 1. The Red Sea- Dead Sea project 29
Box 2. Jordan Valley Irrigation Network........ 51
Box 3. Note on Impact of Water Quality on Agriculture and irrigated farming systems in the Jordan Valley 55
Box 4. Indebtness in the Jordan Valley........ 72
Box 5. Poor farmers with surface irrigation in the middle of the valley 75
Box 6. Note on date Palm trees 92
Box 7. Well’s renting and water consideration in open field vegetables farms in the Highlands........ 95
Box 8. Olive Fruits and Olive Oil Market in Jordan 118
Box 9. Technical Characteristics of production systems within the Lower Jordan River Basin in Jordan 126
Box 10. Farmer’s Relations to Water........ 131
Box 11. A short story about a large intensive entrepreneur’s farmer........ 159
Box 12. Impact of the quotas’ suspension on the bananas farms profitability........ 169

I. INTRODUCTION

Jordan is one of the most water-scarce countries in the world since the water availability rate only reaches 170 m^3/ca/year while it is generally admitted that there is a situation of 'water poverty' if this rate is below 500 m^3/ca/year. This situation is the result of the rapid and global economic development as well as the high population growth Jordan has known during the last fifty years and which have been accompanied by a rapid and global process of mobilization and control of the rare Jordanian water resources. Within this general process of economic and social development, the *Lower Jordan River Basin in Jordan* has played -and continues to play- a role of the highest importance since this *Basin* represents the region of Jordan with the most important potential of economic development gathering 83% of the population, 80% of the agriculture and supplying the country with 80% of its water resources.

Moreover, during this last fifty years, agriculture -in a favourable economic context- has been considered -and effectively was- one of the driving forces of a more global development. However the situation has now changed and since 1995 and the official recognition of the 'Jordanian Water Crisis', the priority is to meet the domestic water needs of the population as well as the needs of the industrial and tourist sectors. In addition, the agriculture still using 70% of the water resources of Jordan is highly involved in the actual overexploitation of the water resources, jeopardizes its future uses at low cost and thus raises some questions. Within the *Lower Jordan River Basin in Jordan*, almost all the surfaces resources are actually controlled and used while the renewable groundwater resources are exploited at 180% of their sustainable rate. In this highly non sustainable situation, a more sustainable water management is thus needed and could only be reached thanks to a decrease in the agricultural fresh water use. The future of the Jordanian agriculture and notably of the irrigated agriculture has thus to be questioned. The different changes in water management now occurring -or to occur in the near future-; driven by the actual scarcity and aiming at a reducing of the agricultural water use actually suggest some evolutions of the Jordanian agricultural sector. The aim of this report is precisely to assess the future possible changes of the irrigated agriculture in the *Lower Jordan River Basin in Jordan.*

After a quick and general presentation of the main characteristics of the *Lower Jordan River Basin in Jordan*, of its history and of the general consequences of the actual water resources overexploitation, we will address the irrigated agricultural sector in Jordan. This assessment will be based on a general agricultural zoning and on a technical description of the main farming systems developed within the *Basin.* This field-knowledge will allow us to determinate how these farming systems will evolve in front of some changes in water management previously identified. These conclusions obtained at the 'farm and farmer' level will thus be enlarged at the river basin scale in order to depict what could be the future landscape of the irrigated agriculture in Jordan. Peculiar attention will also be given to the effective impacts of the changes in water management as far as decrease in agricultural water use and 'savings' of freshwater are concerned.

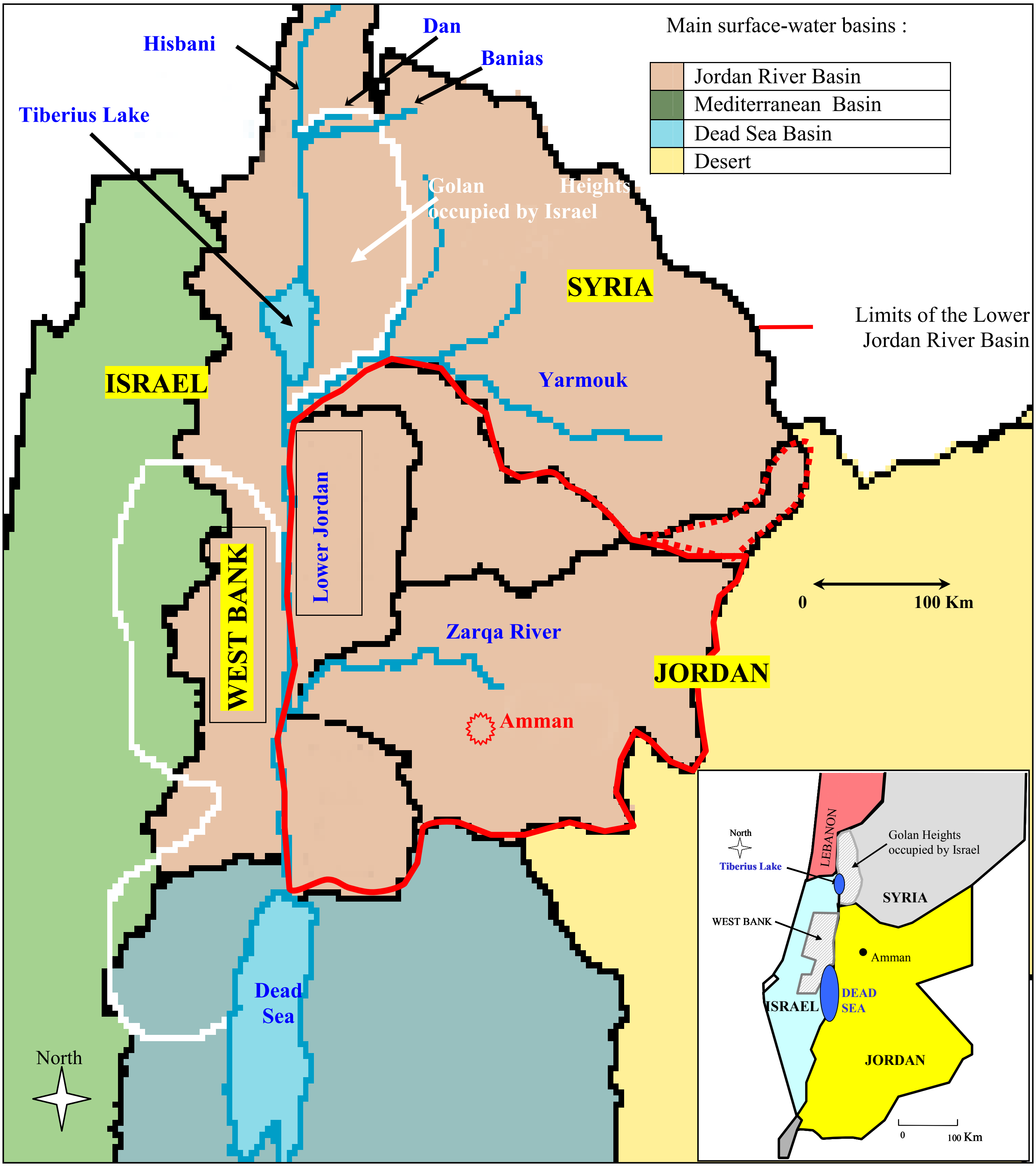


Figure 1. Limits and drainage area of the Lower Jordan River Basin in Jordan

II. A NON SUSTAINABLE EXPLOITATION OF THE WATER RESOURCES

II.1 FOREWORD

Within the first section of this report, we will briefly present the main geographical and hydrological characteristics of the *Lower Jordan River Basin in Jordan* as well as the main steps of its historical development. To have a more complete description of these two points, please refer to the bibliographical report written by *Venot (2004)*[2]. We will then focus on the consequences of the actual unsustainable exploitation of the water resources.

II.2 CHARACTERISTICS OF THE LOWER JORDAN RIVER IN JORDAN

II.2.1 General presentation

The Jordan River is a multinational river, draining a total surface of about 18 000 km². Its three headwaters tributaries originating from the slopes of the Mount Hermon drain the Upper Jordan River Basin and flow southward into the Tiberius Lake. They are the Hisbani, coming from Lebanon, the Banias, coming from Syria, and the Dan coming from the Syrian Golan Heights, now occupied by Israel since 1967. The Jordan River flows then southward in a nearly 130 km-long longitudinal depression named the Jordan Valley before it is discharging into the Dead Sea. This Valley results from a continental rift which led to a lowering of the floor until 400 meters below the Sea Level.

10 km downstream of the Tiberius Lake, the Lower Jordan River receives the waters from its main tributary: The Yarmouk. Before any use of the water resources, this river coming from the North-East in Syria contributed to almost half of the Lower Jordan River flow –the other half coming from the Upper Jordan River.Several temporary flows, of a lesser importance if the Zarqa River coming from Amman is excluded, named *'Side Wadis'* come from the two mountainous banks and feed the Lower Jordan River.

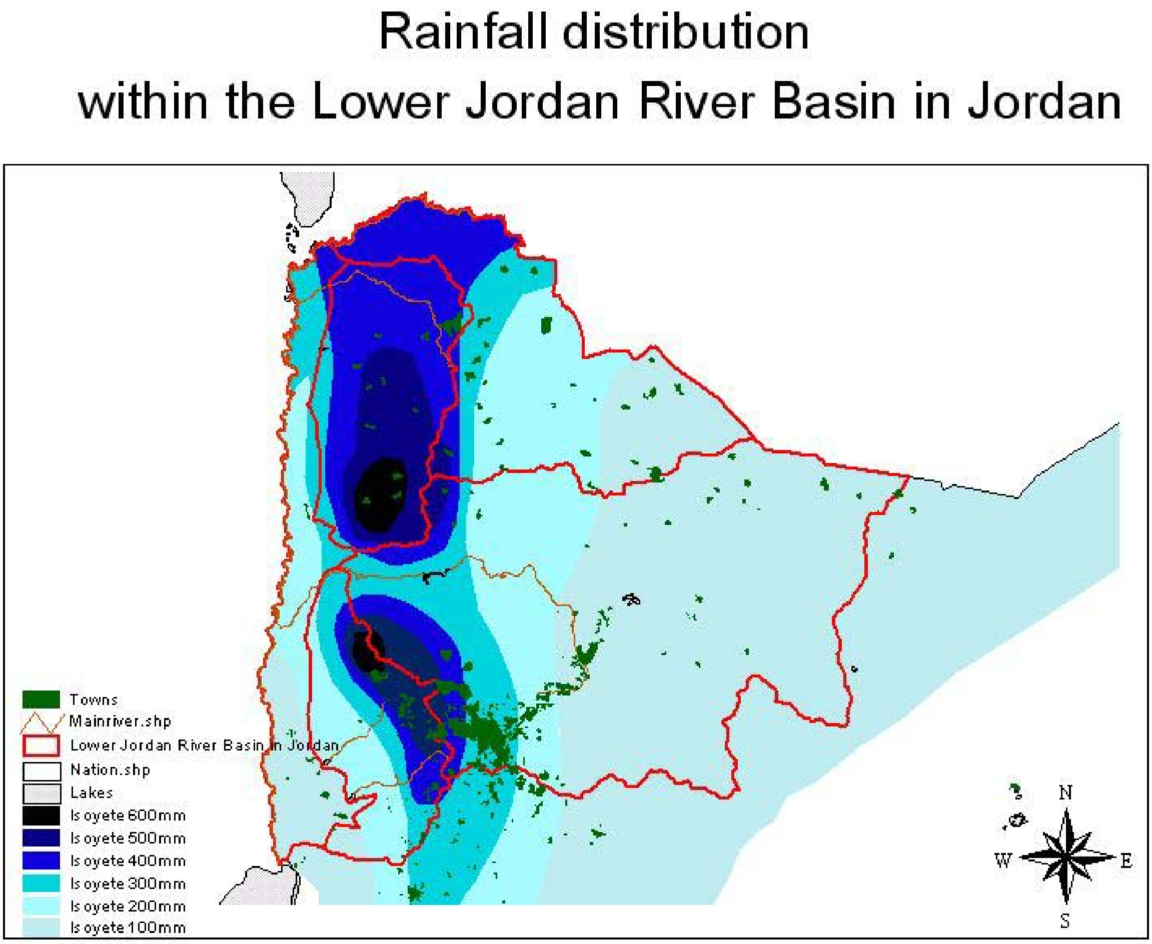
Before any water development projects, the annual flow of the Jordan River into the Dead Sea reached 1.100 to 1.400 Mcm/year[3].

Any consideration on the international conflicts linked to the Jordan River Basin will be excluded of this study and we will only present the stakes linked to water management within Jordan. Our study is thus limited to the Jordan part of the East Bank of the Lower Jordan River Basin. In surface it represents 40% of the entire Jordan River Basin and 7,8 % of the Jordanian territory (Cf. map besides).

The Lower Jordan River Basin in Jordan[4], as defined above, is the wettest area in Jordan and supplies 80% of the national water resources. It is a region where 83 % of the population is concentrated and where the potential of economic development is the highest. Moreover, the agriculture, which uses 70% of the national water resources, is also mainly concentrated in this area as we will see in the following section.

---

[2] This bibliographical report, indissociable from the present one, will also provide you with a graphical and figured description of the evolution of the water balance in the Lower Jordan River Basin in Jordan.
[3] Mcm/year: Million cubic meter per year
[4] The following terms : '*the Basin*', and '*the Jordanian Jordan River Basin*' will be equally used to refer to the Lower Jordan River Basin in Jordan



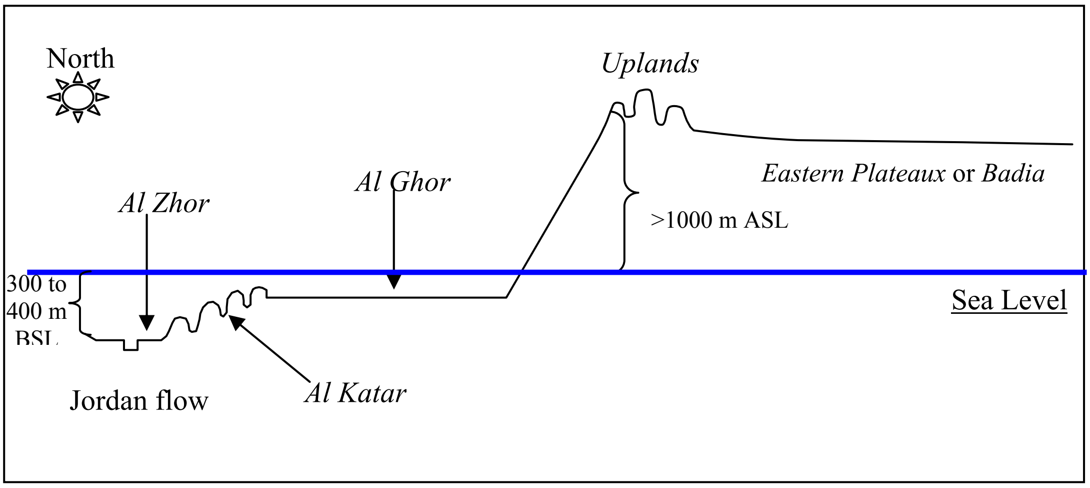


Figure 2. Rainfall distribution in the Lower Jordan River Basin in Jordan

Figure 3. Topography of the Jordan River Basin in Jordan

II.2.2 Morphologic Characteristics

The Basin, as the country, is divided into two main areas: the Jordan Valley and the remaining referred here by the term *Highlands.*

- The ***Highlands*** are constituted by a mountain chain running alongside the Jordan Valley and by some desert plateaux spreading easterly to Syria and Iraq. Of about 30 km large, with an altitude included between 0 and 1000 meters above see level, the mountains, constituted by some sedimentary rocks –essentially limestone- are incised by several *Side Wadis* draining the surface waters to the Jordan River. These mountains, receiving around 400 to 600 mm of rain per year with a peak in January-February, are the rainiest areas of the country. Snow falls can be observed when the altitude exceeds 700 meters. Historically covered of forests essentially constituted with Mediterranean conifers, mainly olive trees and stone-fruits trees can now be found.
  The plateaux have an altitude of around 600 meters and are mainly used to crop cereals near the mountain in the area where the main urban agglomerations are concentrated and where the rainfalls are still sufficient. More east, the precipitations become rarer (from 200 to 300 mm/year), and only a nomadic Bedouin livestock farming can be found.

- The **Jordan Valley** depression lies from the Yarmouk River in the north to the Dead Sea in the south[5]. Its altitude is included between 200 (in the North) to 400 meters (in the south) below sea level, in consequence the valley can be considered as a natural greenhouse. Actually, temperature increases of around 1°C each time the altitude decreases of 100 meters. Temperatures are thus moderate during the winter (between 15°C and 22°C on average between November and March) and reach some record levels during the summer, regularly exceeding 45°C during the day in the months of June, July and August. The climate is semi-arid on the north (precipitations of 350 mm/year) and arid in the south (50 mm/year near the Dead Sea)

The Jordan River flows into a 30-to-60 meters deep gorge in a narrow alluvial, fertile plain locally called *Al Zhor*, large of 200 meters to 2 km and which can be flooded during some exceptional swellings. The remaining of the valley called *Al Ghor* in Arabic is a fertile area formed by colluviums (diluvia material) eroded and washed down from the neighbouring mountains and deposit over saline lacustrine alluvial sediments of the Lisan Lake which was covering the area from the Tiberius Lake to the dead Sea until 14.000 years from now. Slowly sloping (1,5 to 2,5 %) from the mountains, it is appreciatively 20 km-large in the south, and narrows to 4 Km in the middle to finally widen to 10 km in the north. In these two areas, the soils are deep and of good quality but, because of the climate, only a steppe and some pasture land existed before the reclamation of the valley -if are excluded the cultures developed once a year thanks to the water level drop.

II.2.3 Hydrological description[6]

(i) General presentation

Total rainfalls in Jordan have been estimated to 8,5 Billions of m^3/year (2,1 of m^3/year falling within the Lower Jordan River Basin); 85% of these precipitations are lost into evaporation, 5% flow into the rivers and the remaining 10% infiltrate to recharge the aquifers.

(ii) Surface waters

[5] The Jordan Valley defined here is the northern part of the Jordan Rift Valley which is constituted with, this valley excluded and from north to south, the Dead Sea and the Wadi Araba on a total length of 360 km.
[6] Are presented here the annual average of the natural flows and the average annual recharge of the aquifers

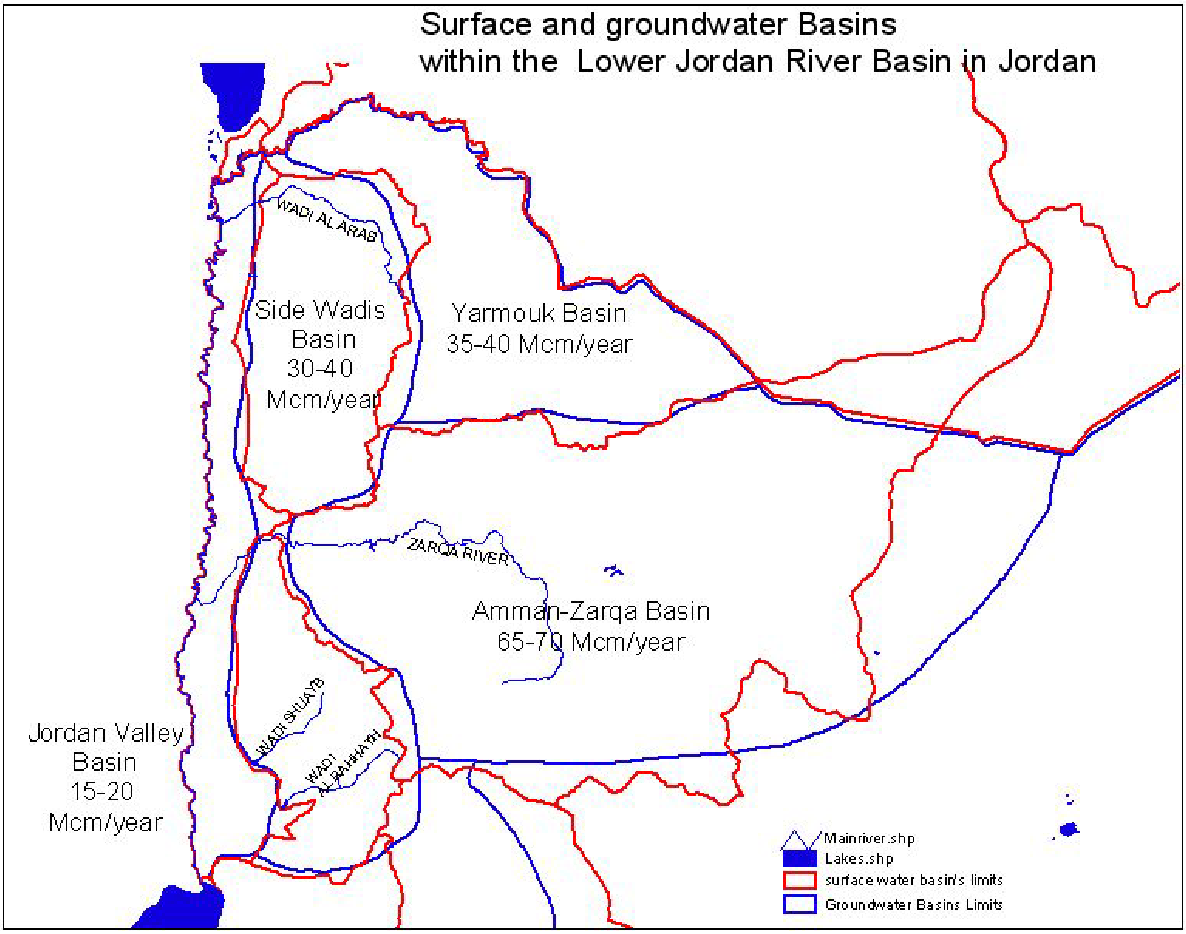


Figure 4. Groundwater and Surface water Basins in the lower Jordan River Basin

Surface waters of the *Basin* mainly come from the Upper Jordan (605 Mcm/year), the Yarmouk (440 to 470 Mcm/year come from springs and rivers mainly located in Syria) and the Zarqa Rivers (90 Mcm/year) as well as from several Side *Wadis* incising the mountains (90 and 30 Mcm/year respectively for the northern and the southern *Side Wadis*)

(iii) Groundwater

The Basin is made up of four groundwater Basins: The Amman-Zarqa Basin[7] (the annual recharge within Jordan reaches 65 to 70 Mcm/year, the total recharge 88 Mcm/year), the Yarmouk Basin[8] (the annual recharge within Jordan reaches 35 to 40 Mcm/year- total recharge of 90 Mcm/year) the *Side Wadis* Basin (annual recharge of 30 to 40 Mcm/year) and the Jordan River Basin (the annual recharge within Jordan reaches 15 to 20 Mcm/year for a total recharge of 30 Mcm/year)[9].

II.3 Some Words on History: A Rapid development

II.3.1 The Situation in 1950: The pre-exploitation phase

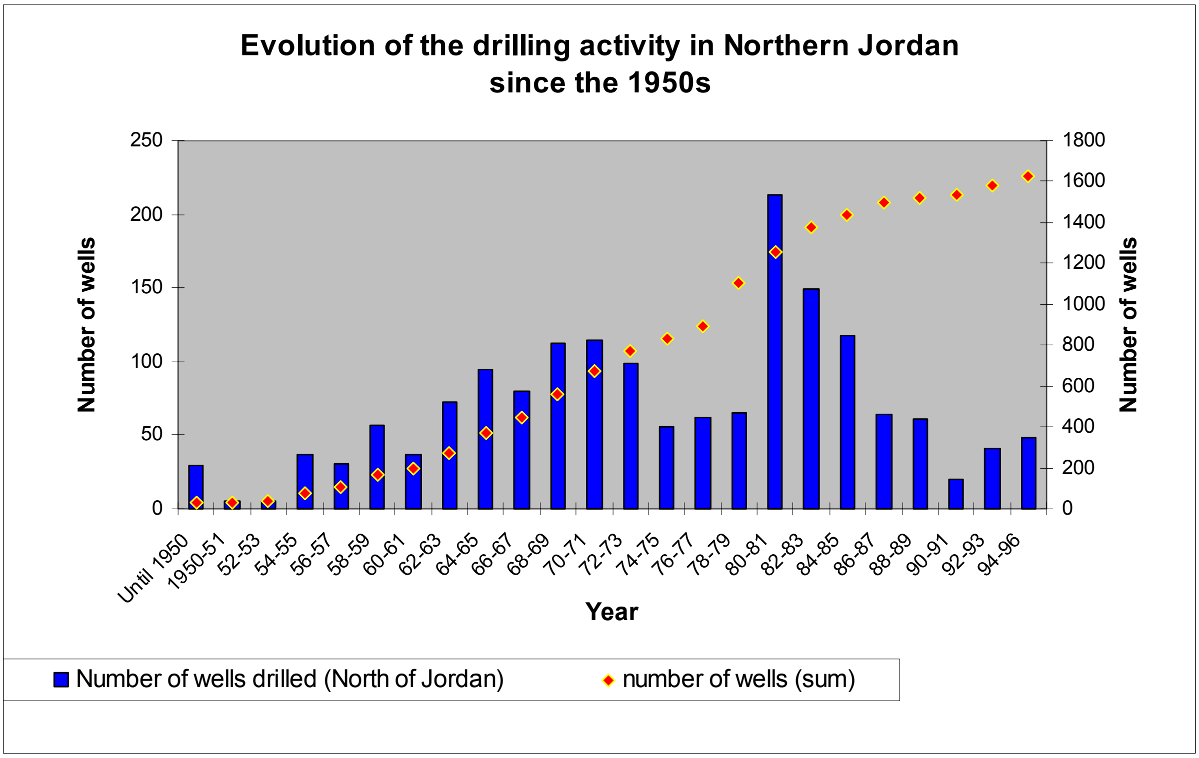
The Jordan River Basin is considered as one of the humanity cradle. Already from 6.000 before Jesus Christ (J.C), thanks to -between other things- a less arid climate than today, the first domestication of animals and plants have been observed and allowed the development of the first cities (Jericho). Since then, the Jordan Valley has known fluctuating periods of development, stagnation, and declining as well as several successive political changes. The region has thus, by turns, be under the control of the Arameans, the Edomites, the Greeks, the Romans, the Byzantines (Umayyad), the Ottomans and the British. We could quote, within other things, a prosperous period around 700-800 after J.C when the Umayyad used the entire Jordan Valley to grow sugar cane before the production in the south of Italy ruled the market. On the contrary, the ottoman period (900-1920 after J.C) was a stagnation period of a province located at the empire's periphery. With the British mandate (1931-1946), a beginning of development has been observed but it is mainly the United Kingdom's (Balfour declaration in 1917) and the international community's (through the League of Nations) supports to the setting up of a Jewish state which open the way to the radical modifications of the water resources management in the Jordan River Basin. Within this context, several studies of hydraulic development of the area (irrigation and hydro-electricity) and several attempts for a friendly repartition of the water resources between the riparian parties saw the light of day. These ones will be applied only very later and partially.

Until the 1950s, the Jordan Valley was only sparsely populated and was mainly dependant on a subsistence agricultural production limited by the natural conditions which had become more severe, and drier than before. It is estimated than in 1939 the Trans-Jordan population reached 325.000 inhabitants living, almost all, on agriculture and pastoralism. Cities located in the *Highlands* were still not very developed. Amman, for example, gathered only around 100.000 persons while Irbid, which will become the large city in the north of Jordan, had 20.000 inhabitants. On their side, in winter, Bedouins traditionally used the valley where they could find the necessary forages to feed their herds. They were cropping wheat, barley, maize and some vegetables by irrigating them thanks to water coming from the Yarmouk River and from others *Side Wadis.* During the summer, they left with their herd to the fresher mountains where they met some more sedentary population (fellahin) cropping olive trees and cereals.

The techniques which were used at this time: small dams and earth -or masonry- canal allowed, in addition to the domestic consumption, to irrigate, by diverting the water, small perimeters located along the *Side Wadis.* In the *Highlands*, direct pumping into springs and storage into tanks also

[7] 85% of the Amman-Zarqa Basin is located within Jordan.
[8] Two thirds of the Yarmouk Basin lay in Syria.
[9] In the Jordan River Basin, water is brackish or saline.

Figure 5. Evolution of the number of wells in north Jordan since the 1950s
Source: Groundwater Resources of Northern Jordan, BGR-WAJ



<u>NB:</u> After 1992 only very few drilling licenses have been delivered. It has been one of the main policies implemented in order to reach a more sustainable water management in the country. We will see that in spite of this interdiction, the number of operating wells increased during the last decade and we will present some hypotheses to explain this process.

allowed this double use. The cities were thus supplied by neighboring springs. If, during the 1940s the first examples of dams and pumping into groundwater could be observed, these two phenomenons stayed really limited and would only be developed during the 1960s. During the same period, thanks to the first roads, the traditional self-sufficiency agriculture turned slowly towards a marketing of the agricultural production in the cities.

II.3.2 The situation in the mid 1970s: the exploitation phase

Following the 1948-1949 war linked to the creation of the Israel state, a first huge influx of Palestinian refugees (around 450.000 persons) constituted a major challenge for a country which just began its economic development. In 1967-1968, after the six-day war in June 1967, it has been around 400.000 *"displaced persons"* who immigrated to Jordan. The demographic boom (450.000 persons before 1948 and 2 millions in 1975), linked to these 'transfers of population', added to a more global phenomenon of infant mortality's decrease, constitutes certainly the main factor explaining the extremely rapid reclamation of the Lower Jordan River Basin's water resources.

The international community, which has backed up the Israel's creation, has, on another side, strongly supported the economic development of Jordan in order to alleviate the social tensions due to the population displacements and to keep 'stability' within the region. Because of this, the financing of large facilities quickly allowed the development of irrigated agriculture in the Jordan Valley in the framework of a larger socio-economic development process.

In the Jordan Valley, the construction between 1958 and 1966 of a main concrete 69 Km-long canal -King Abdullah Canal, KAC[10]-a land reform allowing the constitution of numerous small intensive fruits-and-vegetables farms, the construction of several roads, some urbanization projects and the development of the basic social services allowed the implementation of the population and the development of a market oriented fruit and vegetables production[11]. The traditional model of agriculture-breeding of the nomadic Bedouins has been replaced in a few years by a modern agriculture, market oriented, which could supply the growing cities and which allowed the production of important surplus which have been exported all around the Middle East. This evolution can be explained by several factors as the agricultural knowledge of the Palestinian refugees, some 'capitalist' initiatives made by large Jordanian families, the international aid's support and some favourable market conditions both in Jordan and in the Middle East.

During this period, in the *Highlands,* the rapid development of the cities and of the irrigated agriculture has been accompanied by the groundwater exploitation –cf. the chart besides. The irrigated agriculture has been developed, on one hand, thanks to several actions of the Jordanian government aiming, since the 1950s, to settle the nomadic tribes of the area and on another hand as a result of private initiatives multiplied during the 1960 and the 1970 thanks to the appearance of new techniques allowing the groundwater exploitation (petrol and electric pumps, drilling boreholes…)

Furthermore, potable water supply in the cities has been allowed thanks to the development of public wells in and near the urban areas. In the cities located near the springs, the wells implied a strong increase of the local resources' exploitation. On the other hand, for some cities, the first water transfers from distant areas were needed. We can, for example, quote the transfers done from the Azraq oasis to the north of the Basin, transfers which will be strongly developed and which will cause the drying up of this wetland.

[10] Initially named East Ghor Canal

[11] A troubled period between 1967 and 1971 has however interrupted this process. The six-day war caused the exodus of all the population located in the valley to the *Highlands* and that is only after 1971 –and four years of internal stability within Jordan closed by the departure of the Palestine Liberation Organization (PLO)- that the Jordanian government has re-launched, on a larger scale, its development actions in the Jordan Valley.

II.4 THE SITUATION IN 2000

II.4.1 Historical Context

To follow the increasing water demand due to the economic and industrial development, to the improving standards of living and to the population growth, the reclamation of the Lower Jordan River Basin in Jordan quickened during the last twenty five years. This mainly led to a growing exploitation of the groundwater resources.

Later, the Jordan water resources and the impact of their overexploitation have been better identified and a new water policy with important reorientation towards a more sustainable management has been announced in 1995.

Between 1975 and 1995, the exploitation of the water resources increased and quickened sharply without that any change in the way to manage the water resources could be quoted even if, in the beginning of the 1990s, some indications suggest that awareness linked to a 'water crisis' was developing.

In the Jordan Valley, the irrigated agriculture has been developed a lot thanks to several hydraulic facilities (doubling of the canal length, implementation of a public pressurized water distribution network, construction of a storage dam on the Zarqa River and other *Side Wadis*). All these investments, mainly financed by the international aid during three decades have been estimated to 1,5 Billions of US dollars[12]. Moreover, thanks to new techniques of production (greenhouses, drip irrigation, plastic mulch, fertilizer, new varieties…), to the access to a immigrant Egyptian labour force, to marketing opportunities (above all until the end of the 1980s), the irrigated agriculture in the Jordan Valley has known a production and an economic profitability boom described by some as the 'Super Green revolution'[13].

While, because of the peculiar climate, the Jordan Valley allows a winter production of vegetables and some fruits withstanding the heat (citrus and bananas), in the *Highlands,* vegetables and Mediterranean fruits can be produced all the summer long. On these desert plateaux, private wells allowed an 'unlimited access' to good-quality-groundwater resources which lead to an investment process allowing the development of an irrigated agriculture supplying Jordan and the Gulf Countries in fruits and vegetables during the summer[14]. In addition to that, in these areas, some well's owners plant olive trees orchards which represent now more than half of the irrigated surface in the *Highlands.* These olive trees orchards seem to us to be caused by the pursuit of a certain social prestige more than by their economic profitability. These plantations, which will never be profitable, are though using water which could be allocated, at low cost, to domestic uses in urban areas and seems to us being, as the bananas production with a good-quality-water in the Jordan Valley[15], one of the main aberration in the water scarce context of Jordan.

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[12] *Suleiman, 2003 & Nachbaur, 2004*

[13] *Elmusa, 1994*

[14] The small and middle-size Palestinian-Jordanian entrepreneurs constituted the main driving force of the rapid fruit-and-vegetables-irrigated agriculture development in Jordan, both in the Jordan Valley and in the *Highlands.* To explain this process, it is useful to remind: the mainly rural origin of the displaced populations, the Palestinian agricultural knowledge, the technology transfers from Israel, the willingness of the displaced populations to develop their activity of production, the existence of important marketing-networks receiving the existence of Palestinian communities within the Gulf Countries and finally the reinvestment in the agricultural sector of these communities.

[15] The culture of bananas in the Jordan Valley (1.350 Ha) would use around 46 Mcm/year of a water of the better quality in Jordan (bananas are highly sensitive to salts). This culture has mainly been developed by some influent tribes traditionally established in the valley and which always have controlled the better and easy-exploitable water resources. This culture constitutes today -and by far- the more profitable crop which can be found in Jordan due to customs barriers which maintain the bananas' local price at a higher level than the price of the international market. With the entry of Jordan in the World Trade organization (WTO) in 2000, some prospects of evolution concerning the custom duties for bananas importation exist but no schedule has been negotiated yet. A more complete description of the bananas-stake will be presented in the following parts of this report.

During the same period, in order to ensure the supply of potable water to the growing cities, it has been necessary both to multiply the number of wells in the surroundings of the cities (between 1975 and 2000, the number of wells used for domestic purposes in the city of Amman increased from 6 to 12) and to mobilized new resources to be transferred to the cities. Now, amman receives therefore, added to the 22 Mcm pumped every year in the municipality, 32 Mcm/year from other wells of which one third is coming from groundwater resources located outside from the Lower Jordan River Basin[16]. Added to this water coming from the *Highlands*, another huge transfer coming from the King Abdallah Canal in the Jordan Valley has to be mentioned. This transfer, initiated at the end of the 1980s has been particularly developed after the huge immigration of Jordanian-Palestinians who were working in the Gulf Countries and who have been forced to leave these countries and to come back to Jordan after the first Gulf war (1991). This transfer (40 Mcm/year) represents today one third of the water supplied in Amman and one third of the water diverted from the Yarmouk to the King Abdallah Canal. Irrigation in the south of the Jordan Valley was already developed (around 3.000 ha) and this transfer became possible only thanks to the concomitant development of the collection and the treatment of waste waters as well as their mixing with fresh water coming from the Zarqa River in the King Talal Dam (KTD) built in 1977. These blended waters have actually replaced the fresh water initially used to irrigate the middle and the south of the Jordan Valley. This process is the only real reallocation within the Basin and was made possible due to a peculiar favourable topographical situation allowing a low-cost transfer of treated waste water from the cities to the irrigated perimeters.

Until the mid 1990s, the water was considered as a 'sleeping resource' and all you have to do was to localize it and to mobilize it thanks to new techniques always more effective and more efficient. The uncertainty on the water resources repartition between the riparians of the Jordan River Basin led to the idea that, what ever could happen, some new resources could become available. The development of the hydrological knowledge and the Peace treaty establishing in 1994 the repartition of the water resources between Israel and Jordan led the country to be aware of its water scarce situation and decided to deflect its water policy towards a more sustainable management.

II.4.2 Unsustainable exploitation and reorientation of the water management policies

The knowledge of each aquifer in Jordan showed that the volume pumped each year were -and still are- very higher than the mean recharge of the aquifers. The overexploitation reaches 150 to 180 % of the annual recharge depending on the aquifer. Consequences are the quick lowering of the water table as well as the increase of the salts' concentration within the aquifers because of the intrusion of brackish or salty waters coming from more saline neighbouring aquifers.

In addition, the demographic growth and the improvement in the living's standards of the entire population led –and will continue to lead- to a strong increase in the potable water needs. That will require the mobilization and the development of new water resources. Furthermore, the exploitation costs of the resources allowing the supply of the urban areas with potable water (investment, operation and maintenance) have strongly increased. It is now actually necessary for meeting the growing needs of the urban population to transfer water on longer distance and to elevate it on several hundreds of meters, two techniques which are energy-consuming (pumping on 1.200 meters from the Jordan Valley or on 200-to-600 meters deep in the wells).

Moreover, it is worth noticing that the agriculture, which met very favourable conditions during the 1970s and the 1980s and which has been strongly supported by the government because it allowed a rapid and economically viable local development, uses today a disproportioned share of the national water resources. Actually, agriculture only produces 2 % of the Gross Domestic Product (GDP), employs 5 % of the working population and nevertheless represents 65 % of the national uses.

[16] The main part is coming from the Azraq Oasis located at 80 km of Amman, the remaining coming from the Dead Sea Basin.

In front of the identified problems and taking into account the scarce character of the water resources effectively available, the Jordanian government, supported by the international silent partners which always have been strongly implicated in the water-sector's investments, has fundamentally reoriented his water management policy. This new policy manifests itself in:

(i) Institutional and resources global management actions

- Official publication of the governmental priorities and objectives within the Jordan's Water Strategy Policies of 1995 and 1997 (priorities given respectively to the potable, then the industrial and finally the irrigation water).
- The concentration of the responsibilities of the public management of the entire sector within a Ministry of Water and Irrigation (MWI).
- The planning of a set of new projects aiming to mobilize the last available resources (dams, transfers, desalinization…).

(ii) Actions aiming to reduce the agricultural water consumption

- Freeze of well's drilling authorizations in 1992.
- Freeze of eligible surfaces for a citrus or bananas water allocation in the early 1990s[17]
- Control of the quantity pumped in the aquifers (installation of water meters in 1994 and groundwater-control By-Law in 2002 establishing a taxation of the volume pumped)
- Modernization of the irrigation systems in the Jordan Valley (shift from a distribution system by open channel to an underground pressurized network –shift ended in 1996)
- Replacement of the freshwaters used in irrigation by blended treated waste water coming from the King Talal Dam (KTD) in order to irrigate the middle and the south of the Jordan Valley.
- Since 1998, annual reduction of the water quotas allocated to the farmers of the Jordan Valley according to the quantity of the resources available in the country.
- Renting and set-aside by the government in order to reduce the demand –and the consumption- of water used in irrigation in the Jordan Valley during the dry years (1.000ha for a value of 0.4 Millions of US dollars in 2001).

(iii)Actions aiming to a better management of the potable water

- Rehabilitation of the supply network of the Greater-Amman city (investment of 250 Millions of US dollars in the 2003-2006 period) in order to reduce the important water leakages which reach almost 30 % of the water delivered.
- Contract to transfer the management of the potable water supply-network of Amman city to a private firm in order to improve the distribution service, the network control and to increase the public takings thanks to the reduction of the unaccounted for water

[17] In 2003, all the surfaces planted with citrus trees between 1990 and 2001 have been 'newly recognized' and receive now a citrus water allocation higher than the vegetable one it received before. That constitutes a step backwards within the direction of a more sustainable water management in Jordan.

II.4.3 Present water balance

(i) Summary table of water resources

In Jordan, water resources are very limited; among the scarcest of any country in the world. The expanding population, the climatic and topographical conditions of the country as well as a generalized development during the last fifty years have led to an enormous pressure on the limited water resources and created severe discrepancy between the water use and the renewable available water resources (cf. table 1 besides). In summer shortages and intermittence of urban supplies are getting severe[18]. Present uses already exceed renewable supplies. The renewable available water resources are about **840** Mcm/year with a total use reaching now the **1065** Mcm/year. Unsustainable practices of overdrawing in both the renewable and the fossil aquifers are now a common behaviour which jeopardizes the Jordan water situation since groundwater levels are actually declining and water quality deteriorating. It is worth noticing that the quantity effectively over abstracted is lower than the Pictures presented here. Return flows from agriculture and from urban and industrial uses have to be considered.

Return flows to the Yarmouk and the Side Wadis basins have been estimated at 15 Mcm/year, return flows to the Amman-Zarqa Basins have been estimated at 50 Mcm/year. The effective abstraction rate would thus respectively reach 111 and 135% of the sustainable rate of the Yarmouk-*Side Wadis* Basin and the Amman-Zarqa Basin.

As agriculture is the most important groundwater user in Jordan, we will try to evaluate it on our own in a following paragraph in order to compare the empirical Picture we obtain to the official Pictures presented by the Ministry of Water and Irrigation

(ii) Some words on Groundwater abstraction in the Lower Jordan River Basin in Jordan

We have previously seen that the number of wells within Jordan increased a lot since the last fifty years at the expense of the sustainability of the groundwater resources. Two measures have been taken to slow down –and even stop- this process. After 1992, no drilling licenses have been delivered and since 1994, all the wells are equipped with water meters allowing to know the quantity of water pumped in each well[19]. Thus it is possible to recount the history of the groundwater abstraction within the Lower Jordan River Basin since this date.

The charts on the following page show the groundwater abstraction in each of the groundwater basin of the Lower Jordan Basin in Jordan. Only the *Side Wadis* Basin is used at a sustainable rate below its annual recharge (82% of the recharge). The quantity pumped in the Yarmouk basin equals its recharge while the Jordan Valley Basin and the Amman-Zarqa Basin are respectively over abstracted by 150 and 208 % (return flows non considered). We observe than since 1995, the exploitation rate of the aquifers decreases (except for the Yarmouk basin for which a slight increase is observed). The quantity of water pumped for industry stays constant around 8 to 9 Mcm/year. In the same time, the quantity pumped for domestic purposes increased of 15% to reach now 123 Mcm/year[20]. The global decrease observed is thus linked to a decrease in the water abstracted for agricultural purposes. We observed that the main decrease occurs in the Jordan Valley Basin (between 1995 and 2003, the agriculture water abstraction decreased from 33 to 18 Mcm/year) and in the Amman-Zarqa Basin (the abstraction decreased from 76 to 58 Mcm/year during the same period). On a global point of view, the

[18] It is worth noticing the situation has been highly improved since 1999-2000, when the Jordanian government has transferred the management of the Greater Amman Municipality water supply-network to a French-Jordanian private company (LEMA-Jardaneh Arabtech Co). Moreover, the intermittence of water supply is more linked to technical issues due to the supply network than really to shortage of water *(Decker, 2004)*

[19] Before this date only public wells were controlled. Last wells which could have been legally dug have been dug before 1994 since the drilling license were valid for two years.

[20] The quantity pumped to be used in the Basin is higher since there are some transfers of water from distant groundwater Basins.

Surface Water resources	Average flow	**Renewable Ground water resources**	Renewable Volume	Abstracted Volume	**Abstraction (% of renewable yield)**	**Volume abstracted from Fossil Aquifers= Non Renewable resources**		**Total Use**	
Yarmouk river	270[1]	Yarmouk Basin+ Side Wadis Basin	45*[1]	65[5]	144				
Peace treaty with Israel	30[2]	Amman Zarqa Basin	90[3] (70 within Jordan)	145[3]	205				
Zarqa river	60[3]	Jordan Valley basin	25[6]	40[6]	160				
NorthSide Wadis flow	65[3]	Azraq Aquifer [α]	25[6]	60[6]	240				
Upper Jordan River	35[4]	Dead Sea Basin [α]	55[6]	90[6]	160				
Amman treated return flow	60[3]	Wadi Araba[β]	15[5]	10[5]	70				
Drainage from Yarmouk Basin	25[3]	Jafr Basin[β]	10[5]	20[5]	200				
rainage from Amman-Zarqa Basin	15[3]	Southern Aquifers[β]	15[5]	1,5[5]	10				
Southern Wadis flow	20 [α5]								
Total Jordan	**580**	**Total Jordan**	**260**	**456,5**	**145**	**Total Jordan**	**65**[7]	**Total Jordan**	**1100**
Total Jordan River Basin	**560**	**Total Jordan River Basin**	**220**	**425**	**180**	**Total Jordan River Basin**	**15**	**Total Jordan River Basin**	**1000**

Table 1. Summary table of the water resources and use in Jordan and in the Lower Jordan River Basin in Jordan

N.B.: As Figures differ from an author to another one, it is impossible to have a unique evaluation. In these conditions, we choose to round off the figures we present at 5 Mcm/year.

[α] These resources are located out of the Basin considered but the water is pumped and used in this one.

[β] These sub-basins are out of the Lower Jordan River Basin in Jordan.

*That is only the Jordanian share of the Yarmouk renewable aquifer. The total renewable amount laying in Syria reach 125 Mcm/yr for *El-Naser, 1991 and Salameh & Bannayan, 1993* and 115 Mcm/year for *JICA, 2003*

[1] According to *El-Naser, 1998*

[2] According to the Jordan-Israel Peace Treaty.

[3] According to *Salameh & Bannayan, 1993*

[4] According to *Orthofer, 2001*

[5] According to *JICA, 2003 (official figures according to the MWI)*

[6] According to *Macoun & El-Naser, date unknown*

[7] *Salman, 2001* and *JICA, 2003. Aabstraction from the fossil aquifer of Disi in the south of the country*

exploitation of the aquifers located in the Basin has decreased from 256 to 240 Mcm/year between 1995 and 2003

On another hand within the same period the number of operating wells in Jordan has increased even if no licenses have been delivered since 1992. Actually there is always a delay between the drilling and the effective use of the well. In agriculture it can be due, for example, to the high investments needed to reclaim the land, or to the absence of someone to rent the well drilled by a rich investor.

Date	1995	1996	1997	1998	1999	2000	2001	2002
Number of wells	1630	1650	1700	1720	1765	1835	1825	1865

Table 2. Number of operating wells controlled by the Water Authority of Jordan in 1995-2002
(Source: hard copy from M.Khair Hadidi (WAJ)[21])

These two observations (decrease of the water abstracted and increase of the number of wells) could only be explained if the average amount pumped in each well has decreased since 1995. Concerning agricultural wells several hypotheses could be done. The farmers could have decreased the water they pumped because they decreased the water they allocate to each dunum, because the surface they crop is lower than before or simply because the capacity of their well has decreased in relation to the water table drop (without any new investments they thus are not able to pumped the same quantity than 10 years ago). There is also a possibility that this observation (decrease in agricultural abstraction) be linked to problems in metering (absence or non-working meters, accuracy or lack of the controls…)

On this point, a detailed study on the process which seems to occur since almost 10 years (decrease in the groundwater abstraction) is needed and could bring a lot of information concerning both the agricultural and the water sector in Jordan since it will focus on one of the main actual problem: the agricultural over abstraction of water. A detailed analysis of the WAJ database[22], linked to field surveys and interviews with users of wells could be an adapted tool to begin this study. It will allow better knowing what could be the future evolution linked to the recent water policy which will be implemented.

II.5 CONSEQUENCES

II.5.1 A headlong rush into more expensive water resources, some pharaonic projects…

The table presented on the following page shows the approximate costs of different projects to increase the water supply in Jordan and notably in Amman. Two kinds of projects can be identified: long distance transfer and desalination. While the historic exploitation costs (from local wells) can be evaluated around 0,2 $\$/m^3$ of water supplied, the exploitation costs linked to the new projects are around 0,7 to 1 $\$/m^3$ and could even reach almost 2 $\$/m^3$ in the case of the Red Sea- Dead Sea project (cf. description on the following page).

[21] Numbers are appreciative since they come from evaluation from a chart.
[22] Gathering since 1995, the characteristics of each controlled well. Even if the accuracy of such database could be discuss mainly because of a clear lack of resources (both human and material), the data are until now not used as they could be.

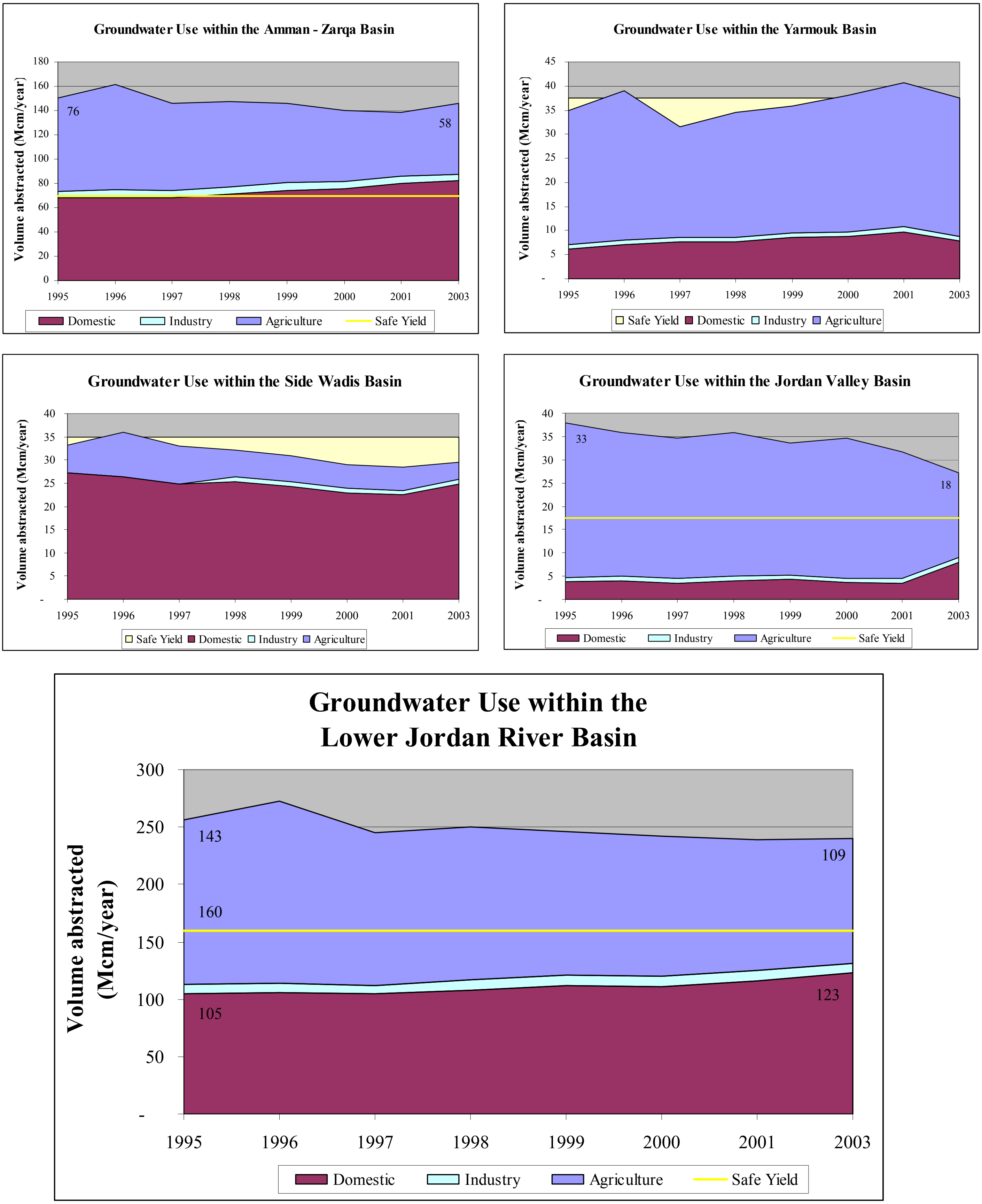


Figure 6. Groundwater abstraction (return flow unaccounted) by kind of use within the Jordan River Basin in Jordan (Source of the figures: MWI-database)

Water Source	Cost Year 2000 JD/m³	Cost Year 2000 USD/m³	Water for use annually MCM
For Amman and Highlands			
Amman network rehabilitation♣ (low)	0.026	0.036	83 to 394 per project
Amman network rehabilitation♣ (high)	0.247	0.346	
From groundwater currently serving farms∇ (low) pumping costs	0.061	0.086	20
From groundwater currently serving farms∇ (high) Pumping costs	0.075	0.105	
Pumping + transfer from local wells	≈ 0,14	≈ 0, 2	
Wehda dam (on Yarmouk) ♣	0.119	0.166	85
Zai-Dabouq conveyor from the valley♣	0.300	0.423	45 (40 now in use)
electricity costs accounts for:	0,24	0, 34	
Pipe from Litani in Lebanon∂	0.484	0.678	150
Sea water desalination Mediterranean-Dead∂	0.510	0.720	800
Disi fossil aquifer♣	0.568	0.801	100
Import by sea in bags∂	0.594	0.831	200
Sea water desalination reverse osmosis plant∂	0.46	0.650	
Import by sea in used tankers∂	0.792	1.108	200
Pipe from Euphrates in Iraq∂	0.792	1.108	150
Brackish water desalination in the Jordan Valley & Transfer	=0,27+0,3	=0,38+0,423	
Import by sea in new tankers∂	0.990	1.386	200
Pipe from Seyhan-Ceyhan in Turkey∂	1.168	1.635	150
Sea water desalination Red-Dead (desalination+ conveyance to Dead Sea)∂	0.716	1,01	850
Transfer from the Dead Sea to Amman (conveyance system) (electric cost of 0,49 $)	≈ 0460	≈ 0,650	570 in Amman
Total Red-Dead project for Amman supply	≈1,171	≈ 1,651	570 in Amman
Mean cost of municipal water charge		≈ 0, 38	(30% of real cost)
Not for Highlands or not for drinking			
Wastewater collection in Northern Governorates♣	0.221	0.310	8,700
Aqaba desalination♣	0.495	0.693	30
Wastewater treatment plant in Salt♣	0.532	0.744	1,300
Wastewater treatment plant in Irbid♣	0.695	0.973	1,850
Wastewater treatment plant in Fuhais♣	1.429	2.001	440

Table 3. Approximate costs of several water supply projects

Sources: ♣**National water master plan, Volume viii: Water sector economics** ***(MWI, year 2003 Dinars).***
∂**Middle East regional study on water supply and demand development,** ***page 27 (GTZ, year 1998 Dinars).***
∇***James Fitch. (USAID, year 2001 Dinars).***
(After Nachbaur, 2004)

Box 1. The Red Sea- Dead Sea project

The idea of a canal from the Red Sea to the Dead Sea is regularly mentioned since decades but the aims pursue have evolved. During the 1970s, and following the two oil booms, Israel conceived it as a hydro-electric project to develop an alternative energetic strategy. This unilateral project has been globally criticized by the international community. At the end of the 1980s, beginning of the 1990s, an Israeli engineering and research department analyzed the idea of a transfer into the Dead Sea to produce desalinated water. It concludes that the transfer from the Mediterranean See to the Dead Sea was economically more interesting than a transfer Red Sea-Dead Sea. In the peace process between Israel and Jordan, the transfer to the Dead Sea is, for the first time, studied in terms of regional cooperation. In this framework, a pre-feasability study is entrusted to the American Harza group which concluded its study in 1997. We will present the project as described in the Harza group study. The main objective is the production of 850 Mcm of desalinated water per year using the process of reverse osmosis (RO) desalination. It is a project with a multi-country venture expected to contribute to the Peace Process in the region through enhancing cooperation between all the parties involved i.e. Jordan, Israel and the Palestinian Authority.

The Red-Dead Project foresees a connection between the Red and the Dead Sea. The difference of water level between the Red and the Dead Seas of about 400 m would offer good conditions for hydropower generation. Generated electric power will be used for the desalination process. 141 km of tunnel and closed pipe as well as 39 km of an open channel are required to conduct sea water from the Red Sea to the Dead Sea, all the conveyance system being constructed within Jordan. The intake structure is planned to be at Aqaba. About 400 km alignment of the transfer pipe will be along Wadi Araba/Arava and will allow transferring 1500 Mcm of sea water per year. A reverse osmosis plant will be located south of the Dead Sea. The capacity of the RO plant will be 850 Mcm/year, while the conveyance system from the Dead Sea to Amman will be 570 Mcm/year[23], the last third will be supplied to Israel and the Palestinian Territory (*Harza JRV Group, 1998).* The integrated scheme of the Red-Dead-Project aims at developing the Jordan Rift Valley comprehensively. Additional benefits (e.g. tourism, industry, agriculture and trade) are expected apart from the benefits originating from the provision of desalinated water. Moreover, one of the main objectives 'newly presented' -or at least emphasize- both by Jordan and Israel at the Earth Summit of Johannesburg in 2002 is to increase the level of the Dead Sea, or at least to halt its decline (*Harza JRV Group, 1998)*[24]. A tripartite comity (Jordan, Israel and Palestinian Authority) appointed the World Bank to do the Term of References for the feasibility study. The project will need ten years to be constructed. From Year 1 to Year 10: construction of the conveyance system from the Red Sea to the Dead Sea and from Year 6 to 10 construction of the RO Plant and the conveyance systems to the cities. 540 Mcm/year will be sold at year 10. This amount will reach 850 Mcm at year 30.

Water and Energy

The total costs of the project has been evaluated at 5 Billions of US $ of whom 1,3 Billions for the Sea Water Pipe (*Harza JRV Group*, 1998). One of the main points to be underline is the energetic cost of such a project. 830 GWh/year will be needed to pump the water at the Red Sea, the difference in altitude should allow to produce the necessary energy to desalinate 850 Mcm of water per year (there will remain a surplus of 140 GWh/year) while the pumping to supply the cities should need between 3960 GWh/year (yield of 88% for the global yield of electric transformation) and 6950 GWh/year (yield of 50%). The added needed Energy for Jordan will be included between 3100 GWh/year (yield of 88%) and 5300 GWh/year (yield of 50%). That represent an increase of 60 to 100% of the actual energetic consumption of Jordan and an added costs of 180 to 318 Millions of Dollars (1 kWh costs 0,06$)

The water costs have been divided as follow: 0,65 $\$/m^3$ for the conveyance system from the Red Sea to the Dead Sea and the Reverse Osmosis plant and 0, 65 $\$/m^3$ for the transfer to Amman (*Harza JRV Group*, 1998). It implies a total costs of water of 1,3 $\$/m^3$. Other evaluation leads to a price of 1,903 $\$/m^3$ (see besides).

Impacts

- The construction will affect the biological diversity notably by disturbing the endangered species of the Dana nature Reserve located at proximity, impacts on precious coral reefs in the Gulf of Aqaba have also to be studied.
- Density stratification is expected through the discharge of concentrated sea water into the Dead Sea. The evaporation from the Dead Sea as well as the precipitation of gypsum through mixing of concentrated sea water with Dead Sea water will certainly increase.
- Due to the import of nutrients algae blooming cannot be excluded. Anoxic conditions in the lower layers of the Dead Sea could be re-established.
- The discharge of sea water into the Dead Sea will have an impact on the sea level. Water from Dead Sea could thus infiltrate into the surrounding ground water which could be polluted. Groundwater could also be polluted from accidental leakages, as a result of a serious seismic event.
- For the potash company, the rise in Dead Sea level may threaten the stability of evaporation pond dikes, which were designed according to the current level of the Dead Sea and may not endure the increased pressure on them. The project will also jeopardize the stability of the dikes during discharge of chemical unsaturated water. It will decrease the efficiency of the mineral recovery process due to the change in chemistry and concentration of Dead Sea. This, in turn, will limit the future expansion of two plants planned northwards *(Harza JRV Group, 1998).*
- An indirect positive impact is the overall improvement in the quality of life for the people in the project area by increasing employment opportunities during project construction and within the tourism sector, due to the anticipated increase of visitors to the area. In the long run, the potential for development will increase, providing more secure socio-economic conditions for the nearby residents.

[23] It corresponds to half of the actual water use in Jordan.
[24] Since the earth summit in Johannesburg the Red-Dead Project is presented as 'the Peace Conduit'.

II.5.2 Environmental degradation

- Introduction

Protected areas, from where water resources could come, do not exist anymore. All the recharge areas are populated and exploited. Agricultural and industrial return flows and inefficient sewage systems are polluting the ground water and the surface water. Due to its overexploitation the water table drops rapidly and some salty aquifers use to contaminate the other aquifers when they reach very low levels. Due to the important agricultural ground water use, 50% of the cities water resources come from surface water that are more easily contaminated (algae, pollutions…). Drinking water being distributed only 1 to 3 days by week, families keep their water in individual storages (cisterns on the roof) that are responsible for severe degradations of the water quality. At the same time, an important part of the irrigated areas receive treated waste water that are more salty and where high contents of suspended solids, heavy metals and algae's create problems in the micro-irrigation systems. No "wetlands" could be protected. The Jordan River itself being an isolated "boarder area", some wild life have survived in the no man's land but the Jordan river itself is highly salty and polluted due to the general brine and sewage disposal. The important oasis of Azraq, close to the eastern limit of the basin has almost disappeared due to the over exploitation of the aquifer (irrigation and transfer to cities). Only by pumping some water, a United Nation Development Program (UNDP) manages to maintain wet a very small protected area for migrant birds and local wild life.

One of the main environmental problems is the very rapid decline of the Dead Sea (an average of 0,5m per year). Only 20% (in average) of the Jordan River historical flow is reaching the Dead Sea (265 Mcm/year out of 1345 Mcm/year and this will almost disappear when the Wehdah dam will be built on the Yarmouk River). The important evaporation of the Dead Sea due to its hot weather and to an important industrial exploitation (production of potash and other salts)[25] also contributes to the rapid decrease of the Dead Sea level. The disappearance of the Dead Sea already has and will have important impacts on tourism with the sea staying each time further from the hotels and some areas around the Dead Sea.

- Aquifer Degradation

Aquifer degradation is linked to two main reasons:

- ✓ Over drafting leading to a water table's drop (cf. Charts besides) and to a degradation of the water quality from salinization of the aquifer.

- ✓ Direct pollution from various other sources such as effluents from wastewater treatment plants, industries, residential compounds without sewer connection and waste disposal sites. Moreover, as far as agriculture is concerned, intensive fertiliser application and leaching of irrigated lands in addition to the above-mentioned effluent infiltration need to be mentioned as potential causes of quality degradation. In several areas groundwater degradation has been observed.

For example, during the 1970s, a huge groundwater irrigation scheme has been implemented in the area of Wadi Dhuleil, Eastern Jordan. Ever since irrigation started, water quality in the aquifer has been deteriorating with an increase in salinity and nitrate contents (cf. chart besides). There are three main reasons for this quality degradation. One is over-abstraction of the groundwater, as a result of the doubling in the irrigated area and the water use by people other than the local farmers. The other is poor irrigation practices, along with lack of adequate supply, which has led to poor salinity control. The last reason is the discharge from the As-Samra Waste Water Treatment Plant into Wadi Dhuleil. Due to the low quality of the discharged effluent contamination of the groundwater aquifers in the area has occurred. In the Jordan Valley basin, over abstraction by the farmers from private wells leads to a salinization of the aquifer while the intensive use of pesticides and fertilizers with high concentration

[25] This industrial exploitation is estimated to cause 30% of the total decrease.

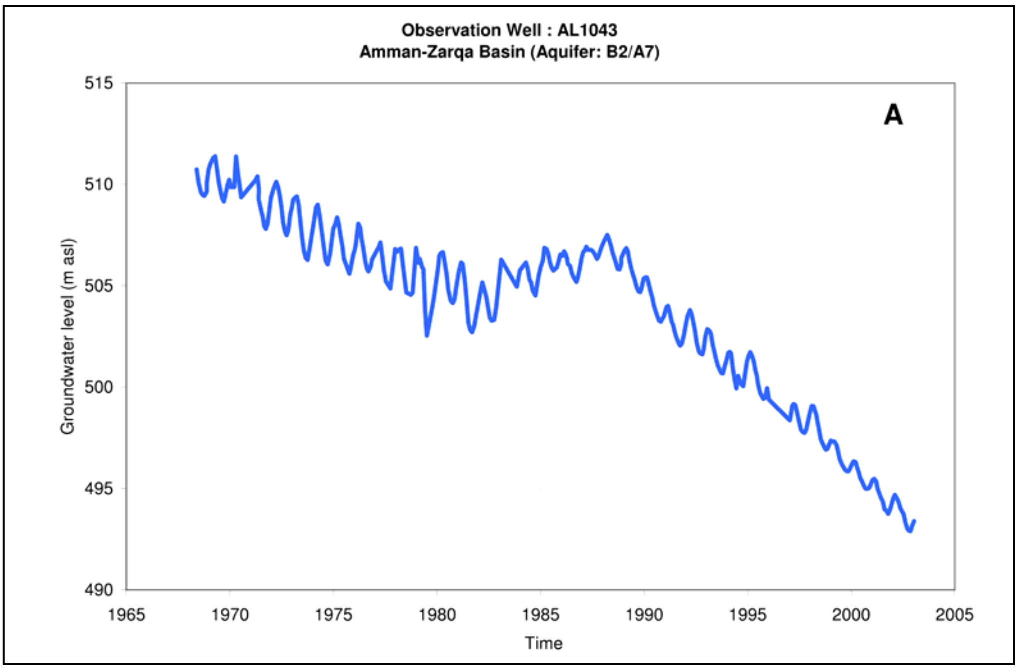


Figure 7. Example of drop in water table in aquifers of the Eastern Jordan (Amman-Zarqa Basin)
(Source: National Water Master Plan, 2004)

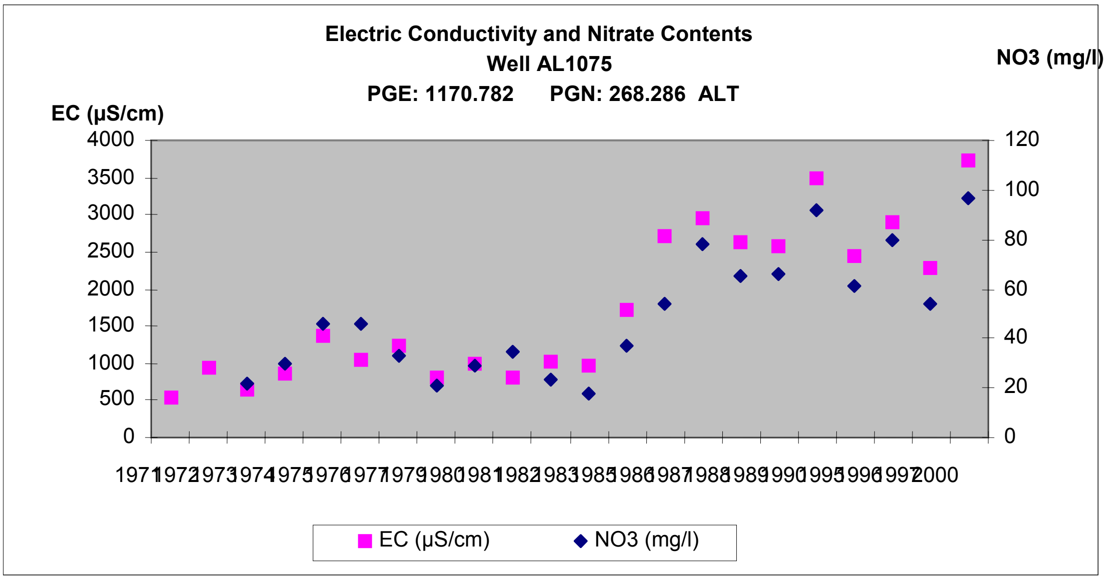


Figure 8. Example of the water quality deterioration in the aquifers of the Eastern Jordan (Amman-Zarqa Basin)
(Source: National Water Master Plan, 2004)

of nitrates causes severe pollutions to the shallow aquifer highly pervious and located about 10 meters deep.

We have developed here two examples, but such processes are highly widespread within Jordan. Protection of groundwater quality and quantity are thus needed. For quality conservation, projects of land use planning are now considered by the relevant authorities. These projects offer the most effective and in principle the less cost intensive tool to protect groundwater. Catchment areas of wells and springs used for the production of public water supplies need to be protected through appropriate land use restrictions according to technical guidelines which have still to be issued by the Ministry of Water and Irrigation

To decrease the rate of over abstraction, controls from the Water Authority of Jordan (WAJ) have to be developed and sanctions have to be taken according to the laws if necessary (fine, payment of fees…)

- The Waste Water Question

Waste water reuse appears to be one of the most suitable solutions to take up the challenge of water scarcity in arid areas. Waste water reuse provides additional water resources, ensures the balance of the natural water cycle and protects the environment. Among all the different ways of using wastewater, agricultural irrigation is the largest consumer. Waste water reuse in irrigation is considered not only as a creation of a new resource but also certainly as a complementary treatment that allows avoiding direct dump into nature.

In Jordan, the use of treated waste water in agriculture will be generalized. From 60 Mcm/year in 2000, it has now reached nearly 75 Mcm/year and it is planned that 240 Mcm/year of treated waste water will be used in agriculture by the year 2025. The quality of the water considered is thus of previous importance. Two different aspects have to be considered: the microbiological quality and the physico-chemical quality.

The microbiological quality (which can be evaluated thanks to the quantity of intestinal nematodes and fecal coliforms) is important concerning the public health protection. The treatment plants are built to control this microbiological quality. In Jordan, the main treatment plant (located in As Samra)[26], receiving waste water from the municipalities of Amman and Zarqa as well as from other villages in the same area is now functioning above its capacity[27]. The quality of the effluent is thus declining and it causes severe damage to the environment and threatens the public health (cf. table besides).

The physico-chemical quality is important to be considered as well as the treated waste water is reused in agriculture. The quantity of fertilizing elements and the salinity have some consequences on crops and soils and have to be carefully considered. The high concentration of fertilizing elements improves the agronomic value of wastewater; however, these nourishing elements could be a restrictive factor in the case of extreme input due to a high concentration or to an important wastewater input. Salinity of the treated waste water leads to an increase of the soil salinity as well as an enrichment of sodium, chloride and sulphate ions which implies a change in the soil solution composition. The increase of the electric conductivity and the accumulation of heavy metals could lead to the restriction of certain crops, especially those which are sensitive to salt[28].

- Desalination

One of the major environmental problems related to desalination is the disposal of the brine water produced by the treatment process and which could have a negative impact on soil and vegetation cover in the *wadis*, on groundwater resources in the surrounding areas and on the Jordan River (and Dead Sea eventually). The brine may also affect springs that are used by the farmers. So

[26] There are 19 treatment plants within the country.
[27] A contract of 150 millions of Dollars has been signed with a private company in order to increase the capacity of the plant in order to improve the effluent quality.
[28] This question will be addressed in further details within this report when we will present the future scenario we envisaged concerning the Jordanian agricultural sector.

Parameter	Unit	Existing As-Samra Effluent Quality (2000) (Average)	Jordanian Specifications (893/2002) for Wadi Discharge	Comments
Dissolved oxygen (DO)	mg/l	3	>1	
pH	-	8	6-9	High
Total Dissolved Solids (TDS)	mg/l	1212	1500	+/-OK
Fat, oil and grease (FOG)	-	27	8.0	High
Total suspended solids (TSS)	mg/l	149	120	High
Biological Oxygen Demand "5" (BOD5)	mg/l	144	60	High
Chemical Oxygen Demand (COD)	mg/l	503	300	High
Phosphate (PO4)	mg/l	17	15	High
Total Nitrogen	mg/l	-	75	
Nitrate (NO3)	mg/l	82	45	High
Bicarbonate (HCO3)	mg/l	858	400	High
Chlorine (Cl)	mg/l	389	350	High
Total Faecal Coliforms (TFCC)	MPN/100ml	50018	1000	Very high
Chromium (Cr)	mg/l	0.04	0.02	OK
Lead (Pb)	mg/l	0.05	0.2	OK
Zinc (Zn)	mg/l	0.19	5.0	OK

<u>Source:</u> National Water Master Plan, 2004.
According to: WAJ Laboratory;
TOR of As Samra Waste Water Treatment Plant

far, the impact of brine disposal in Jordan has not been studied. Therefore, countermeasures for these impacts have yet to be developed.

- Wetlands Degradation: The Azraq Case

Abstraction of groundwater from the Azraq basin started in 1982, when Amman Water Sewerage Authority (AWSA) drilled fifteen wells within the northern parts of Azraq Oasis in order to supply Amman and Zarqa cities with their domestic water needs. Water was also pumped from this basin for irrigation purposes within the surrounding area. The groundwater abstraction from the aquifer reaches now 54 Mcm/year (in 2002) while the average annual direct recharge rate is about 25 Mcm/year. In 1977, the site of the oasis was declared a nature reserve of international importance and was included in the Ramsar List of Wetlands and is now considered a protected area under the mandate of the Royal Society for Conservation of the Nature. There are no local laws protecting this site from development projects, but there are international *'regulation'* such as the *Ramsar Convention* and the *Convention on Biological Diversity*. Apart from its historical importance, the reserve contained water birds and more than 20 species occurring in internationally important numbers (though a survey has not been conducted since 1992), as well as fish and plant species not present anywhere else in the world, such as the endemic Azraq Killifish (*Aphanius sirhani*). Nevertheless, in 1992, the two springs forming the oasis ceased to flow and the wetland dried out due to continued over-extraction of the groundwater below, even though the government prohibited the drilling of new wells. The drop in groundwater level also led to salinization of the aquifer below *(Ramsar Bureau, 1998).*

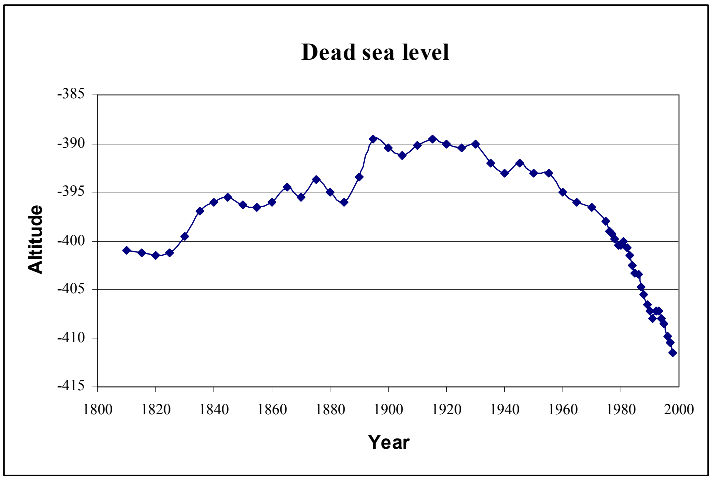
The Ramsar Bureau that visited the site in 1990 recommended the following water-related measures in order to protect the Azraq Oasis: Reduction in the level of water exploitation; total annual exploitation not to exceed the 'safe yield', control of extraction from private wells; pursuit of the possibility of using small quantities of water from middle aquifer to supplement spring flow into the wetland; further research on the hydrological and geological situation affecting the oasis; increased efficiency of water distribution; construction of storage reservoirs to aid groundwater recharge, to be conducted after a proper environmental impact assessment study *(Ramsar Bureau, 1990).*

In 1994, a plan for the rehabilitation of the wetland was initiated. The government started supplying the Oasis with 1,5 MCM/year of water obtained north of the site, in the middle aquifer. Nevertheless, this amount is not enough to offset the impact of the ongoing over-abstraction and the Oasis is still drying up. The rehabilitation program also included protecting the wetland by fencing and guarding it, research and monitoring activities, local participation and public awareness campaigns.

- Decline of the Dead Sea

Since the late 1950s, the level of the Dead Sea Basin has witnessed extensive water development activities that have lead to its decline from about 392 m below mean sea level in 1958 to about 411 below sea level in 1998 (cf. chart besides). Since surface and groundwater sources within its catchment area contribute to the amount of water available in the Dead Sea, their exploitation has been a major factor in this decline. The potash exploitation on the two banks of the Dead Sea has also been one of the main causes of the Dead Sea level decline (it is actually recognized that this exploitation is responsible of one third of the decline through the evaporation ponds implemented to exploit potash). The chart besides illustrates the decrease in the amount of water flowing into the Dead Sea. The levels of the surrounding groundwater aquifers are higher than the Dead Sea one. However, a further drop in the Dead Sea level will increase the hydraulic gradient resulting in an increased drainage of groundwater into the Dead Sea *(Salameh and Naser, 2000)*

This decline has also resulted in expanses of barren, hyper saline mudflats, which have led to a reduction in landscape values in the surrounding areas. The tourism sector has therefore been negatively affected, as the Dead Sea shore constantly recedes further away from the hotels surrounding it. Other possible impacts of the current drop in sea level include land-collapse, as well as percolation losses affecting the two companies that extract minerals from the Dead Sea *(Harza JRV Group 1998).*



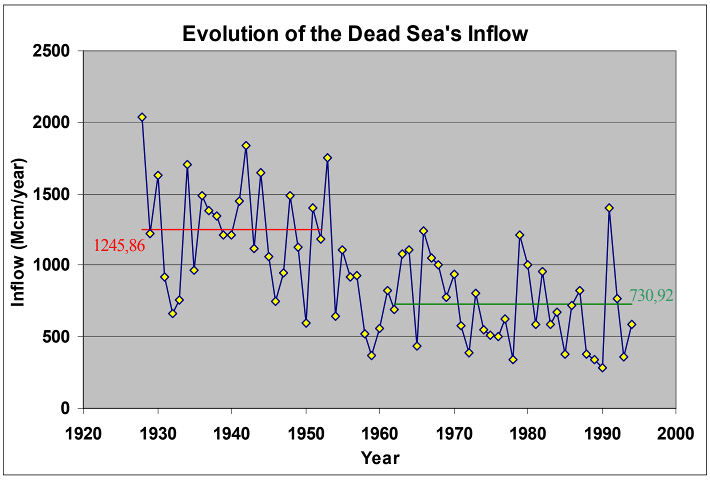


Figure 9. Evolution of the dead Sea level

Source: Arab potash Company

Figure 10. Evolution of the Dead Sea's inflow

Source: **Harza JRV Group.** (1998, February).
Jordan Rift Valley Integrated Development Study.
Red Sea-Dead Sea Canal Project.
Prefeasibility Report. Volume 1-Main Report.

Picture 1. Terraces on the Dead Sea Shore

The Red-Dead project described above is expected to have major positive environmental impacts. It includes the restoration of Dead Sea level to its natural, pre-1960s level thereby improving the declining landscape and enhancing the potential for tourism. This will also enhance the habitats of the unique flora and fauna that inhabit the pockets of freshwater between the springs and the Dead Sea *(Tahal, 1996)*. The most ecologically important of these species are globally threatened birds such as the Griffin vulture, lesser kestrel, as well as vertebrates such as leopards, hyenas, the Nubian ibex, rock hyrax and jungle cat *(GCEP, 1998)*. According to *Salameh and El-Naser (2000)* raising the level of the Dead Sea will result in refilling of the groundwater aquifers along the coastline, which is another anticipated positive impact.

II.5.3 Questions rose up by the irrigated agriculture.

The future of agriculture in Jordan raises a complex set of technical, economic and social questions. Some of these questions are presented here and will be studied in further details in the following parts of this report.

- The irrigated agriculture in the *Highlands* has been mainly developed thanks to important private investments (minimum of 200.000 $ per farm for the wells, pumps, irrigation system and often fruit trees orchards). The 500 to 1.000 investors concerned belong to the high society (deputies, senators, entrepreneurs, scheikhs…) and their influence on the governmental decisions let us think that all the measures aiming to reduce the water rights obtained when the government did not control volumes pumped will be hard and long to implement.

- As it has already been initiated in the Jordan Valley, now receiving the treated waste water from Amman instead of the freshwater coming from the north and now transferred to the capital, the agricultural use of blended treated waste water will be generalized . A degradation of the agricultural water quality will follow and will raise a complex set of problems: workers and consumers' contamination, soils degradation, clogging of irrigation system's emitters, abandonment of certain sensible crops (strawberries, beans, citrus…), consumer's lack of confidence in the quality of the products, drop in prices, loss of certain export markets…

- Allocation of water in the Jordan Valley have already decreased, prices of water increased but it has never constitute –until now- a true handicap for the Jordanian agricultural production. It is mainly the possibilities of marketing which constitute the main problem of the producers. The Jordanian irrigated agriculture has been mainly developed within a time (1975-1990) of strong regional fresh products' demand. These products could be sell for high prices because of the payment capacities of the population in the gulf countries (Oil booms of 1973 and 1979) and of the lack of true competition, notably in Winter (production in the Jordan Valley) and in Summer (production in the *Highlands*). At this time the necessary investments (greenhouses, irrigation system, well, equipment…) secured a return within a few years and a lot of investors developed an agricultural activity since agriculture constituted one of the economic sector among the more profitable. After 1985, the quick development of the production in Jordan and in the region (citrus in Syria, vegetables in Syria, Lebanon and gulf countries) leads to a drop in prices and in the profitability of the investments.

- Jordanians are important consumers of fresh vegetables (tomatoes, cucumbers, eggplants, zucchinis, onions…) all the year long. The reduction in the local production could lead to an increase in prices of these common products which could have negative impacts on the budgets of the poorest families.

- Irrigated agriculture, because of peculiar climatic conditions, allows the development of important fruits and vegetables exportations now representing, on average, 16% of the Jordanian exportations. Due to the strategic character of these agricultural exportations, any reduction of the production will raise macro-economic questions. Actually, if importations of cereals (sometimes defined as ‘virtual water’) have never been discussed within Jordan[29], the maintaining of the high-value-crops’ exportations seems to be essential to stabilize the balance of trade showing a strong deficit in a country with only few natural resources (potash and phosphates of the Dead Sea)

- Jordan has favoured the development of new economic sectors (tourism, services, industry) and signed several agreements[30] which could reappraise the profitability of certain agricultural productions still protected in Jordan (bananas, apples, grapes)

- Another problem, social, is linked to the fact that two thirds of the workers in the agricultural sector are migrants, mainly coming from Egypt and that the majority of the entrepreneurs have a Palestinian origin. It allows to some groups of the Jordanian society to maintain that the social impact of a drastic reduction of the irrigated agriculture would only have little impact on the Jordanian society.

- Until now, the public services have never implemented the laws aiming at a reduction of the agricultural groundwater abstraction by the private wells (quotas, taxes if overrun of the quota…) while it could have been possible thanks to the generalized installation of water meters on the wells from 1994. The owners of private wells in Jordan consider actually that they own the resources they use and because of their influence, they prevent the governmental decisions which could affect them. In addition to that, because of lack of fines on private wells, and of public prices highly subsidized in the Jordan Valley, the farmers only bear a limited share of the exploitation costs of the water. Thus, the farmers are not motivated to save water and the illusion of the existence of resources available at low costs is kept.

[29] In areas where rainfed cereals can be grown, the possible improvements in term of yields and volume are very small. On another hand, the development of irrigated cereals has never been important, the preference being given to vegetables and fruits.

[30] World Trade Organization, Jordan-UE agreement, Great Arab Free Trade establishing a free trade area between the Arab states, several bilateral agreement, notably with the USA and Israel.

III. LESSONS FROM SURVEYS-Agro-economic diagnosis-

Part 1: Agricultural Zoning

III.1 PROBLEMS RAISED UP BY AN EVALUATION OF THE IRRIGATED SURFACES

III.1.1 Introduction: different sources of information

Until now, one of the main problems of an assessment of the Jordanian agricultural sector is the appraisal of the irrigated surfaces in Jordan. Each year, data are available from the department of statistics for each governorate but two problems about these evaluations can be presented here:

* These statistics do not differentiate the irrigated and the rainfed agricultural areas.

* Data on governorates are not accurate to determine the agriculture surfaces within the Jordan River Basin since limits of governorates and limits of the Groundwater Basin are not matching.

Concerning the *Highlands*, an important project has been realized by the American cooperation (USAID-ARD[31]) during the years 1999 to 2001 on the Amman-Zarqa groundwater Basin -which constitutes 52 % of the Lower Jordan River Basin's surface- but no clear evaluation of the irrigated surfaces has been presented despite of the existence of a work done on several satellite images. The only mean to obtain an evaluation of the irrigated surfaces in this area is indirect and consists in doing a multiplication between the average surface of farms and the number of farms, which have been evaluated within the USAID-ARD study.

In 2004, within the framework of a program developed by the MWI and the GTZ[32] and known as the Water Sector Planning Support Project, a landuse has been realized thanks to a Geographical Information System (GIS). The GIS shape file has been obtained thanks to an analysis of two mosaics LandSat Images[33] respectively dated of August 1999 and May 2000. Thanks to a comparison between the two images and to some field test it has been possible to differentiate ten classes of land use: bare rock, forest, water, natural vegetation and -what is the more useful for us- irrigated annual crops (vegetables and cereals), irrigated deciduous trees (mainly stone-fruit trees), non-deciduous irrigated trees (olives, bananas, citrus trees), rainfed annual crops, rainfed deciduous trees and non-deciduous irrigated trees[34]. That consists in an important progress in order to evaluate the irrigated surfaces within the results but we will see that this new evaluation raises some problems and present important contradictions.

III.1.2 Presentation of the results

The tables on the following page present diverse evaluations of the irrigated surfaces within the *Lower Jordan River Basin in Jordan* which have been realized. They are important means to lead to a better knowledge of the Jordanian agricultural sector.

For the Jordan Valley, we both present the evaluation realized by the Department of Statistics (DoS) in 2002 and the one done thanks to the interpretation of the LandSat images[35].

[31] United State Agency for International Development-Associate in Rural Development Inc

[32] Ministry of Water and Irrigation/ Deutsche Gesselshaft für Technische Zusammenarbeit (German cooperation Agency)

[33] 11 images are necessary to cover the entire Jordan.

[34] The comparison between an image taken in August and the other one in May being central to differentiate the irrigated and the rainfed areas

[35] In the Jordan Valley, the evaluation of the irrigated surfaces thanks to the GIS-analysis, has been done according to the limits of the directorates used by the DoS in its evaluation. It is worth noticing that the administrative limits correspond quite well to the limits of the Jordan River Watershed and of the Jordan River

	Irrigated Surfaces within the Jordan River							
	Evaluation of the DoS (2002)				Data From GIS Analysis (1999/2000)			
Surface in dunums	North valley	Middle-Valley	South-valley	Total Valley	North valley	Middle-Valley	South-valley	Total Valley
Trees crop	72 500	19 200	14 900	**106 600**	79 319	21 006	16 302	**116 627**
Olives	4 200	1 300	1 400	6 900	4 595	1 422	1 532	7 549
Citrus	62 200	10 900	1 800	74 900	68 051	11 925	1 969	81 945
Bananas	2 800	460	10 400	13 660	3 063	503	11 378	14 945
Grapes	-	3 100	-	3100	-	3 392	-	3 392
Dates	-	1 700	-	1 700	-	1 860	-	1 860
Others	3 300	1 700	1 300	6 300	3 610	1 860	1 422	6 893
Seasonal crop	35 700	52 000	16 200	**103 900**	39 058	56 891	17 724	**113 673**
Barley and Wheat	15 100	8 300	3 200	26 600	16 520	9 081	3 501	29 102
Vegetables	19 000	39 900	11 600	70 500	20 787	43 653	12 691	77 131
Others	1 600	3 800	1 400	6 800	1 750	4 157	1 532	7 440
Total	108 200	71 200	31 100	**210 500**	118 377	77 897	34 025	**230 300**

Irrigated Surfaces within the Highlands of the Lower Jordan River Basin							
Surface in dunums	Side Wadi Basin		Amman-Zarqa Basin		Upper Yarmouk Basin		Total
	surface	%	surface	%	surface	%	surface
Annual Crops	34 758	86	11 862	10	7 255	15	53 875
Deciduous trees	1 819	4	37 795	31	24 423	49	64 037
Non-deciduous trees (mainly olive trees)	4 064	10	72 535	59	17 670	36	94 269
Total	40 641	100	122 192	100	49 348	100	212 181

Table 4. Irrigated Surfaces within the Lower Jordan River Basin in Jordan
(Draw from the GIS-land use analysis)

NB: 1 dunum= 0,1 hectare

groundwater Basin. We considered it was not necessary to do several evaluations for the three kinds of delimitations, we only have considered one zoning and one evaluation and assumed there will not be any differences –or at least negligible- if the two others hydrological zonings were considered.

We can observe that the surfaces derived from the GIS-analysis are always higher that the Pictures presented by the DoS, even if quite similar. A simple explanation can be given: the GIS-analysis allows us calculating the gross irrigated area while the Pictures of the DoS evaluate the net irrigated area (paths, buildings excluded…)

- In the North, citrus are the most frequent crop (57% of the surface), vegetables and cereals being also important (17 and 14% of the total irrigated surface).
- In the Middle, bananas, wheat and olive trees are negligible in the area but we can note that grapes and dates are cropped. Citrus still represent 16% of the surface cropped and vegetables are the major crops with 56% of the surface.
- In the South, bananas and vegetables are the two main crops. Bananas represent 33.5 % of the surface and vegetables 37 %. We will see in the model described in the following pages than bananas and vegetables crops are closely linked.

For the *Highlands*, we present an evaluation of the irrigated surfaces drawn from the GIS-analysis. Only three categories can be done: annual crops, deciduous trees and non-deciduous trees[36]. We chose to present the Pictures for each groundwater basin because as agriculture in the *Highlands* is mainly done thanks to groundwater exploitation, it seems to us to be the relevant division. Actually, thanks to the evaluation of the irrigated surfaces, and to the effective crop consumption we could have an idea of the agricultural exploitation of the groundwater resources for each aquifer. These calculated Pictures will be compared to the official Pictures of the Ministry of Water and Irrigation. We will see further that there are some differences between these two ways of calculation and we will try to understand why. In the actual context of overexploitation of the aquifers, this appraisal is of central importance to know if reaching a sustainable rate of exploitation is feasible and at what price for the agricultural sector could it be possible –both at the national and at the farmer level.

- In the *Side Wadis* Basin, irrigated trees orchards only represent 14 % of the irrigated surface (10 % for olive trees) and vegetables 86 %.
- In the Upper Yarmouk Basin, the situation is the opposite since trees represent 85% of the irrigated surface (49 % of non deciduous trees) and vegetables 15%
- In the Amman-Zarqa Basin, the proportion is appreciatively the same than in the Yarmouk Basin: 90 % of trees (59 % of olive trees) and 10 % of annual crops (vegetables and forages along the Zarqa river).This evaluation of the irrigated surfaces raises some problems.

This one actually does not correspond to the evaluation which has been done by the USAID-ARD study in 2001. *Fitch (2001),* based on a expansion of results obtained during field surveys and on the data reported by the department of Statistics actually advanced the following Pictures: 39 % of olive trees, 18% for other trees, 39% for vegetables and 4 % for cereals without giving any global evaluation of the total irrigated surfaces.

We can suppose the analysis of the satellite images leads to an under estimation of the annual-crop irrigated surfaces. It seems actually hard to differentiate irrigated and rain fed annual crops. Some of the irrigated areas could thus have been classified as rainfed crops. In the following sections and when we will have to deal with irrigated surfaces at the Basin scale to draw some general conclusions, we will present the results according to three different evaluations of the irrigated surfaces: the one drawn from the GIS analysis, another from the USAID-ARD one and the last one will be an intermediate one we consider as the most probable for the area considered.

[36] We will assume that irrigated annual crops in the Highlands are vegetables since irrigated cereals are very rare, non deciduous trees are olive trees and deciduous trees are all the other trees (apple, peach, grape…)

We think that within the 147.990 dunums (evaluation drawn from the GIS-analysis) of rainfed annual crops in the Amman-Zarqa Basin, it is possible that the 21.340 dunums located within the Eastern Desert could be irrigated.

In the Amman-Zarqa Basin, this new evaluation we consider as the most accurate to depict the reality will thus lead to the following Pictures: 37.795 dunums (26%) of irrigated deciduous trees, 72.535 dunums (50%) of irrigated non-deciduous trees and 33.202 dunums (24%) of irrigated annual crops. The total irrigated area will thus reaches 143.532 dunums in the Amman-Zarqa Basin and 233.521 dunums within the entire Lower Jordan River Basin.

We can see here the GIS determination of the land-use constitutes an important tool to evaluate the irrigated surfaces but it raises some important problems and **more studies have to be leaded on this point to determinate with accuracy what are the irrigated surfaces within the *Highlands* in Jordan.** This point is of central importance in order evaluate the agricultural ground water abstraction jeopardizing the Jordanian water resources. In the following paragraph we will try to evaluate the groundwater abstraction in the two main groundwater Basins that are the Yarmouk and the Amman-Zarqa Basin. For the Yarmouk Basin we will use the sole evaluation of irrigated surfaces we have and which has been realized thanks to the GIS-Analysis[37]. For the Amman-Zarqa Basin, we will use three different evaluations and compare the results we will obtain. The *Side Wadis* Basin is not considered since most of the irrigation can be done thanks to surface water flowing into *Wadis*[38].

III.2 Discrepancy between several Evaluations of the Agricultural Groundwater Abstraction

III.2.1 Mode of evaluation

The aim of this section is to compare different evaluations of the agricultural groundwater abstraction in the Amman-Zarqa and the Yarmouk Basins.

Our own evaluations are based on a simple assumption:

Total abstracted water (m^3) =
Irrigated Area thanks to groundwater (dunum) *
Water consumption per surface unit (m^3/dunum)

We have seen the problems raised up by the evaluation of the irrigated surfaces within the Basin. We will use the evaluation of the GIS-analysis for the Yarmouk Basin and the three following evaluation for the Amman-Zarqa Basin:

Surfaces in dunums	Annual crops	Olive trees	Other trees	Total
Evaluation of the GIS-Analysis (E1)	11.862	72.535	37.795	122.192
USAID-ARD evaluation[39] (E2)	52.543	47.655	21.994	122.192
Evaluation of Venot[40]. (E3)	33.202	72.535	37.795	143.532

Table 5. Several evaluations of the irrigated surfaces in the Amman-Zarqa Basin

[37] Even if it is possible that the irrigated surfaces planted with annual crops are underestimated
[38] For the record, we think surfaces of irrigated trees in the *Side Wadis* basin have been underestimated
[39] The total surface considered is the same than for the Evaluation E1 (GIS-Analysis). Only the crop repartition changes.
[40] Same evaluation than the GIS analysis for the trees. For the irrigated vegetables, some plots classified as rainfed annual crops through the GIS-analysis and located in the eastern desert are added to the irrigated annual crops. The irrigated surfaces are thus increased by 21.340 dunums.

We personally think the GIS-data are accurate if trees are considered. On another hand the evaluation E1 seems to us to underestimate the irrigated surfaces planted with annual crops while the evaluations E2 and E3 may over estimate it. The evaluation E2 seems to us to under estimate the surfaces planted with trees

We will do the following hypothesis: in the Yarmouk and the Amman Zarqa Basin, if we exclude the perimeters located along the Yarmouk and the Zarqa rivers we can assume than all the other perimeters are irrigated thanks to groundwater. Thanks to the GIS-maps we can obtain an evaluation of the area irrigated thanks to groundwater.

Concerning the water consumption of crops we will use several evaluations. The water consumption evaluated by *Venot (2003)* through field surveys, the crop water requirements according to an evaluation done during the USAID-ARD study and an average scenario will be successively used. In order to compare our calculations to the official Pictures of the Ministry of Water and Irrigation, we will present the official agricultural groundwater abstraction for the years 1999 and 2000[41].

[41] It is worth noticing the records of the ministry show a decrease since then -cf. part II.4. It is generally admitted that a leeway of about 30% have to be consider for evaluation of the water consumption drawn from field interviews with farmers. The figures of agricultural water consumption presented by the Ministry are based on water meters' reading. The questions of maintenance and tampering of the meters is thus of central importance to have an accurate evaluation of the water abstraction but raised some problems since the meters are distant one from another and are not protected in some closed boxes. Thus, in spite of important progress (equipment and renewing of most of the meters since ten years) , not enough attention is turned on this point and more care is needed.

		Irrigation thanks to groundwater						possible irrigation by surface water	
		Eastern Desert			Upper Yarmouk Area	Transition Area	Suburban Area	Zarqa River	Uplands
Irrigated surfaces (dunums)		E1-GIS analysis	E2- USAID-ARD study evaluation	E3-Venot evaluation	Only one evaluation according to the GIS-analysis				
Amman-Zarqa Basin	Annual Crops	1.263	41.944	22.603		851	203	2.677	6.868
	Olive trees	61.840	36.960	61.840		2.061	360	8.075	199
	Other trees	29.507	13.706	29.507		4.679	926	2.357	326
Yarmouk Basin	Annual Crops	2.198			7.164				8.306
	Olive trees	17.197							0
	Other trees	24.412							326

Table 6. Irrigated areas of the Amman-Zarqa and the Yarmouk Groundwater Basins according to the agricultural zoning

Water consumption (m3/dunum)	***Scenario 1:*** Actual water consumption according to *Venot (2003)*			***Scenario 2:*** Net Water requirements according to *Fitch (2001)* for the eastern desert, the transition area and the Zarqa river. Otherwise water consumption according to *Venot (2003)*			***Scenario 3:*** Intermediate Water consumption between the two first scenarios		
	Annual Crops	Olive trees	Other trees	Annual Crops	Olive trees	Other trees	Annual Crops	Olive trees	Other trees
Eastern Desert	1000	350	1000	615	690	1000	750	350	1000
Upper Yarmouk Area	450	350		450	350		450	350	
Transition Area	1000	350	1000	615	690	1000	750	350	1000
Suburban Area	500	350	1000	500	350	1000	500	350	1000
Zarqa River Area	475	350	850	475	690	920	475	350	850
Uplands	450	350	850	450	350	850	450	350	850

Table 7. Different Scenario of Water consumption according to the agricultural areas

We can observed that the main differences between the evaluation of *Venot (2003)* and the evaluation of the Net Water requirements done by the USAID-ARD study in 2001 concern vegetables and olive trees. For vegetables the evaluation of *Venot (2003)* is much higher than the one presented by the USAID-ARD study, it is the contrary for irrigated olive trees. That can be linked to the fact the USAID-ARD evaluates the water requirements while water consumption has been focused by *Venot (2003)*

III.2.2 Results

Pictures of irrigated areas according to the agricultural zoning as well crop water consumption are summarized in the two tables besides. It allows us evaluating the agricultural ground water abstraction in the two basins. We present below several possible evaluations.

	Scenario 1 *(Water consumption according to Venot, 2003)*	Scenario 2 *(Water requirement USAID-ARD)*	Scenario 3 *(Average)*	Pictures of the Ministry of Water and Irrigation (volume of groundwater abstracted)
Entire Amman-Zarqa Basin (E1-surface evaluation)	69,9	91,4	70,8	**Amman Zarqa Basin** **63,6 Mcm** in 1999 and **58,4 Mcm** in 2000 (58 Mcm in 2003) *Average on 1999/2000: 61 Mcm*
Entire Amman-Zarqa Basin (E2-surface evaluation)	77,5	84	75,9	
Entire Amman-Zarqa Basin (E3-surface evaluation)	91,3	104,6	86,9	
Amman-Zarqa Basin (irrigated areas in the Zarqa River and Uplands areas being subtracted) E1-Evaluation	59	77,6	58,5	
Amman-Zarqa Basin (irrigated areas in the Zarqa River and Uplands areas being subtracted). E2- surface evaluation	72,7	70	63,5	
Amman-Zarqa Basin (irrigated areas in the Zarqa River and Uplands areas being subtracted). E3- surface evaluation	80,4	90,7	74,5	
Entire Yarmouk Basin	39,8	43,5	39,3	**Yarmouk Basin:** **26,3 Mcm** in 1999 and **28,4 Mcm** in 2000 (28,7 Mcm in 2003) *Average on 1999/2000: 27,35 Mcm*
Yarmouk Basin (uplands area and perimeters along the Yarmouk river being excluded)	35,8	40,2	35,3	

Table 8. Different ways to evaluate the agricultural water abstraction in the Amman-Zarqa and the Yarmouk groundwater Basins

This table clearly shows the importance of an accurate evaluation of the surfaces irrigated thanks to groundwater since the results presented above are quite different from one evaluation to another one[42]. Water requirement are also central. An accurate knowledge of these two points needs to be developed to evaluate and understand the agricultural abstraction of water within the groundwater units.

Secondly we can say that, for each evaluation of the surface, the scenario 2 based on the net water requirements calculated by the USAID-ARD study always leads to higher (or at least similar) evaluations of the ground water abstraction than in the scenarios 1 and 3. That is due to a high evaluation of the net requirements for olive trees. Concerning the Amman-Zarqa Basin, the evaluation E3 leads to the highest evaluation of the water consumption for the three scenarios considered. That is because the total irrigated surfaces we used in this evaluation are the highest (with a possible over estimation of the surfaces planted with annual crops).

For the Amman-Zarqa Basin, if we consider that all the surfaces are irrigated thanks to groundwater, the lowest estimation we obtain in our scenarios (69,9 Mcm/year) is higher than the one presented by the Ministry. The discrepancy almost reaches 9 Mcm/year i.e. 15% of the official Picture. The average scenario concerning water consumption giving the lowest evaluation of volume of groundwater abstracted is also obtained if the evaluation E1 is considered. The volume pumped reaches 70,8 Mcm/year (i.e. 18 % higher than the official Picture). This last Picture seems to us to

[42] Differences can reach until 25% between the evaluations E1 and E3.

represent the lower limit of the water effectively use in the Amman-Zarqa Basin since we consider low surfaces with an average water consumption. The upper range could be obtained with the scenario 3, evaluation E3 of the surfaces (i.e. 86,9 Mcm, and a over evaluation of 42% if we compared this Picture to the official one)

If we do not consider the surfaces located within the Uplands and along the Zarqa River which can be irrigated thanks to surface water of the *Side Wadis*, we can observe that the evaluations E1 allows obtaining Pictures of water abstracted similar to the Pictures of the ministry for the Scenario 1 and 3 (for the scenario 2, the evaluation is still higher because of a high water consumption for olive trees). The evaluation E2 gives also similar Picture (around 60 Mcm/year) for the scenario 3.However in both cases the irrigated surfaces seems to be underestimated.

We think the most accurate Pictures concerning the water abstraction in the Amman-Zarqa could be the one obtain with the scenario 3 and the evaluation E3: 74,5 Mcm/year (i.e. 22% higher than the Pictures officially presented by the Ministry and 106% of the aquifer safe yield[43])

For the Yarmouk Basin, the lower estimation considering all the surfaces cropped is 45% higher than the Picture presented by the Ministry (the discrepancy reaches 12,5 Mcm/year). If we do not consider the surfaces which can be irrigated thanks to surface water, our lowest estimation is 22% higher than the official Picture (8 Mcm/year) and corresponds to the average scenario (the agricultural abstraction thus represents 94% of the aquifer's safe yield[44]). We can see that the discrepancy between our evaluations and the official one are in the same range for the two basins: from 20 to 25%.

The Pictures presented here have to be considered with precaution since they are based on rough evaluations of the surfaces cropped and of the water consumption of the crops. We think however that the effective water abstraction in each ground water basin could be included between the official Picture presented by the Ministry and a Picture 25 % higher.

Since 2002, the agricultural groundwater abstraction recorded in the Yarmouk Basin has slightly increase while for the Amman-Zarqa Basin the Picture officially advanced for the agricultural abstraction in 2003 only reaches 58 Mcm/year. It means the agricultural abstraction in the Amman-Zarqa Basin would have decreased by 13% within 4 years. As we said it before, there is no clear explanation to this process and a peculiar analysis of the database of the Water Authority of Jordan should give some ideas to explain this process.

[43] The total abstraction in the Amman-Zarqa Basin reaching 155,6 Mcm/year (by computing domestic and industrial official records –average on 1999/2000) i.e. 222% of the aquifer safe yield.

[44] The total abstraction in the Yarmouk Basin reaching 44,2 Mcm/year (by computing domestic and industrial official records –average on 1999/2000) i.e. 118% of the aquifer safe yield.

III.3 AGRICULTURAL ZONING

III.3.1 General mapping

During the field work realized between March and September 2003, the first task has been to identify different agricultural zones. This zoning has been done according to four main interconnected items: the climatic conditions (notably the rainfall), the vegetation, the source of water used to irrigate the land (surface or ground waters), and the farming systems (in its social, economical and agronomical dimensions[45]) –cf. map presented on the following page[46]- and the irrigated surfaces have been evaluated thanks to the GIS-land use analysis despite the problems met and presented above.

The fine knowledge of the processes taking place within a peculiar farming system allied to the global knowledge of the irrigated agriculture in the Lower Jordan River Basin will allow us giving a quantitative idea of what could be the consequences of the water management changes on the Jordanian agriculture, not only at the farming system scale but also at the river basin scale.

Figure 11. Agricultural Zoning in the Lower Jordan River Basin in Jordan
Source: The agricultural areas have been delimited by Venot (2004).The Land use is the property of the Water Sector Planning Support Project (WSPSP, MWI/GTZ). It is the result of a GIS-Analysis of two LandSat Images respectively dated of August 1999 and May 2000.
Reproduction with the authorization of M. Philip Magiera (GTZ/MWI)

[45] Cf. *Venot (2004)* for more precision on the farming system notion used during this study.
[46] To have the complete landuse within the Lower Jordan River basin see *Venot (2004).*

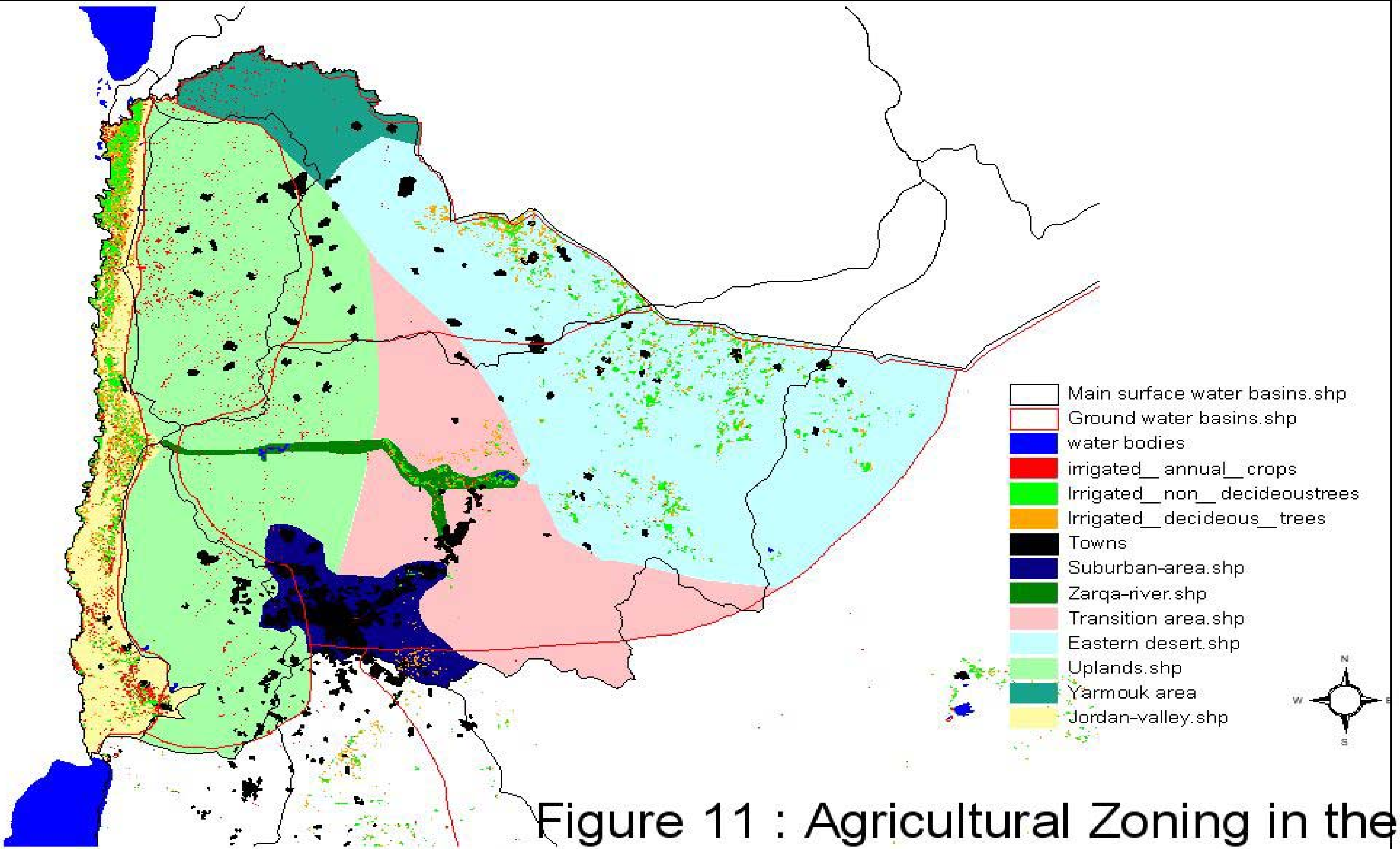


Figure 11 : Agricultural Zoning in the Lower Jordan River Basin in Jordan

III.3.2 The Jordan Valley[47]

(i) General mapping

Through our surveys we have divided the valley in three main parts (as identified in the following map), identified by the following terms: Northern Valley, Middle Valley and Southern Valley. Moreover, we can see that this zoning mainly realized according to the farming systems developed in each area does not correspond to the divisions made by the Department of Statistics and to the administrative divisions of the Jordan Valley Authority (JVA) we used above to present an evaluation of the irrigated surfaces.

(ii) The Northern Valley

We will consider here that the north of the Valley lies from the Yarmouk River (and the village of North Shunah/Addasyeh) to the village of Kreymeh. In this area, there is an irrigation network -cf. description on the following page-, supplying all the farms and managed by the JVA. Within the description of the farming system which will follow, we will consider that the North of the Valley constitute a unique zone. However, this region is not homogeneous and we can quickly present here a more precise zoning organized into two main areas.

[47] See the table 4 (p 26) to have an evaluation of irrigated surfaces

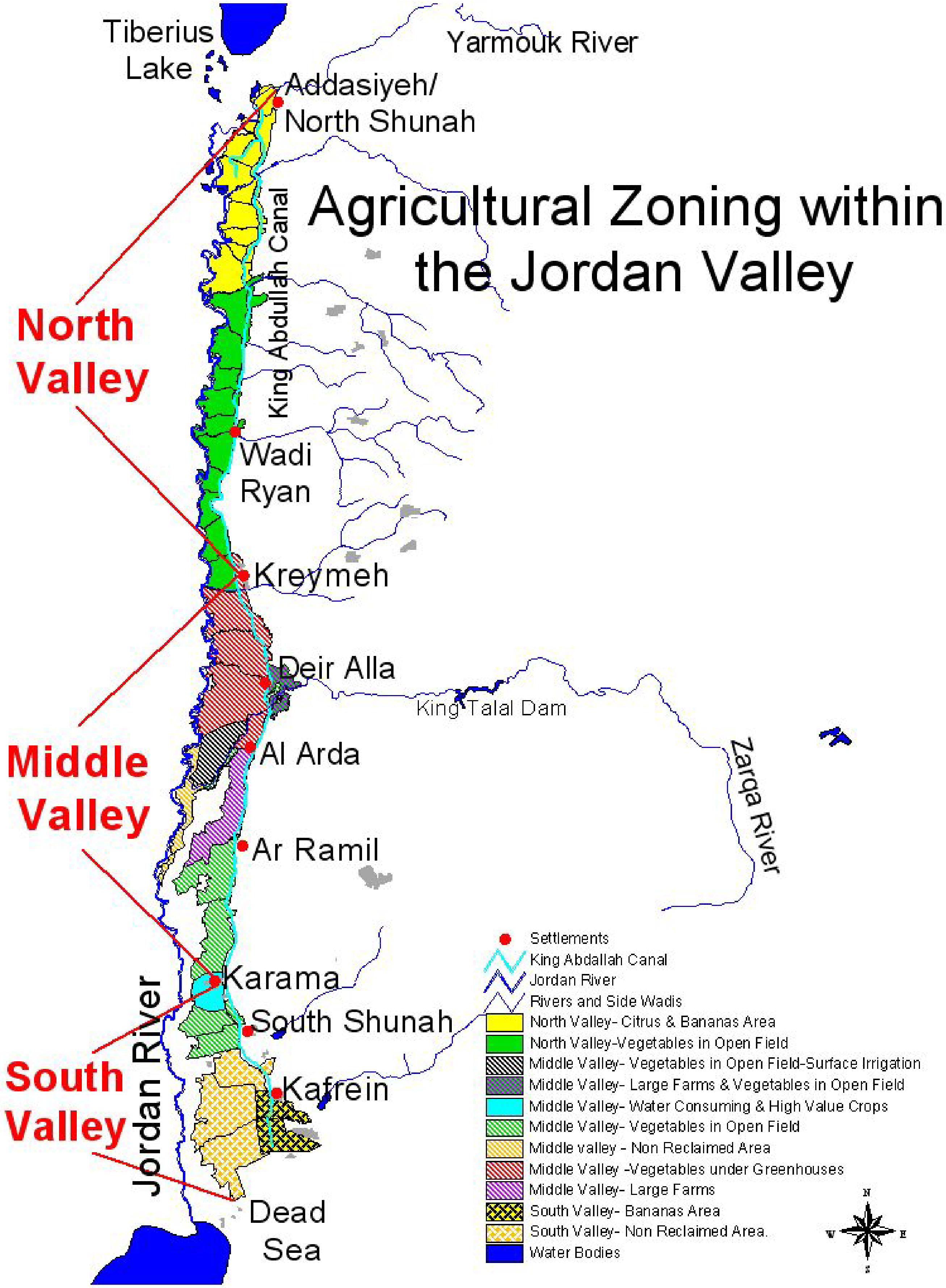


Figure 12. Agricultural Zoning of the Jordan Valley

Box 2. Jordan Valley Irrigation Network

Picture 2. The King Abdullah Canal in the middle of the Valley

Picture 3. A pumping station within the Jordan Valley

The irrigation system in the Jordan valley is organized along the King Abdallah Canal. This 110 km-long concrete canal lies from the north and the Yarmouk to the south and the shores of the Dead Sea. It is an open channel which carries the freshwater coming from the Yarmouk River, other controlled *Side Wadis* and Israeli supplies from the Tiberius Lake. In the north, where the water has a good quality, 40 Mcm/year are diverted to supply Amman. More south, in the village of Deir Allah, the Canal receives the blended water from the King Talal Reservoir. The water quality is thus deteriorating from the north to the south. The irrigated perimeters are managed by the Jordan Valley Authority (JVA) which supply 7.500 irrigation terminals (or FTA: Farm Turn out Assembly) irrigating plots of around 35 dunums . In the south some areas are directly irrigated thanks to water coming from some *Side Wadis*. The system was initially conceived for surface irrigation and during the 1980s and the 1990s, this one has been progressively updated: the canal is now equipped with a modern system of automatic control, several pumping stations taking water from the canal -according to a quota which is allocated to it. Each of these pumping stations supplies pressurized buried systems irrigating around 400ha. In the same time, farmers have invested in on-farm drip irrigation systems. In spite of these important investments the global efficiency of the system is unsatisfactory because of low on-farm efficiency (around 40 to 50%). Pressure and flows supplied are actually heterogeneous (farms located 'upstream' are favoured in comparison with farms 'downstream'), while FTA supply farmers with flows adapted to surface irrigation and not to drip-irrigation. Moreover the use of water meters allowing controlling the supply is still difficult[48].

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[48] A more complete description of water management and irrigation network will be done in a following section of this paper.

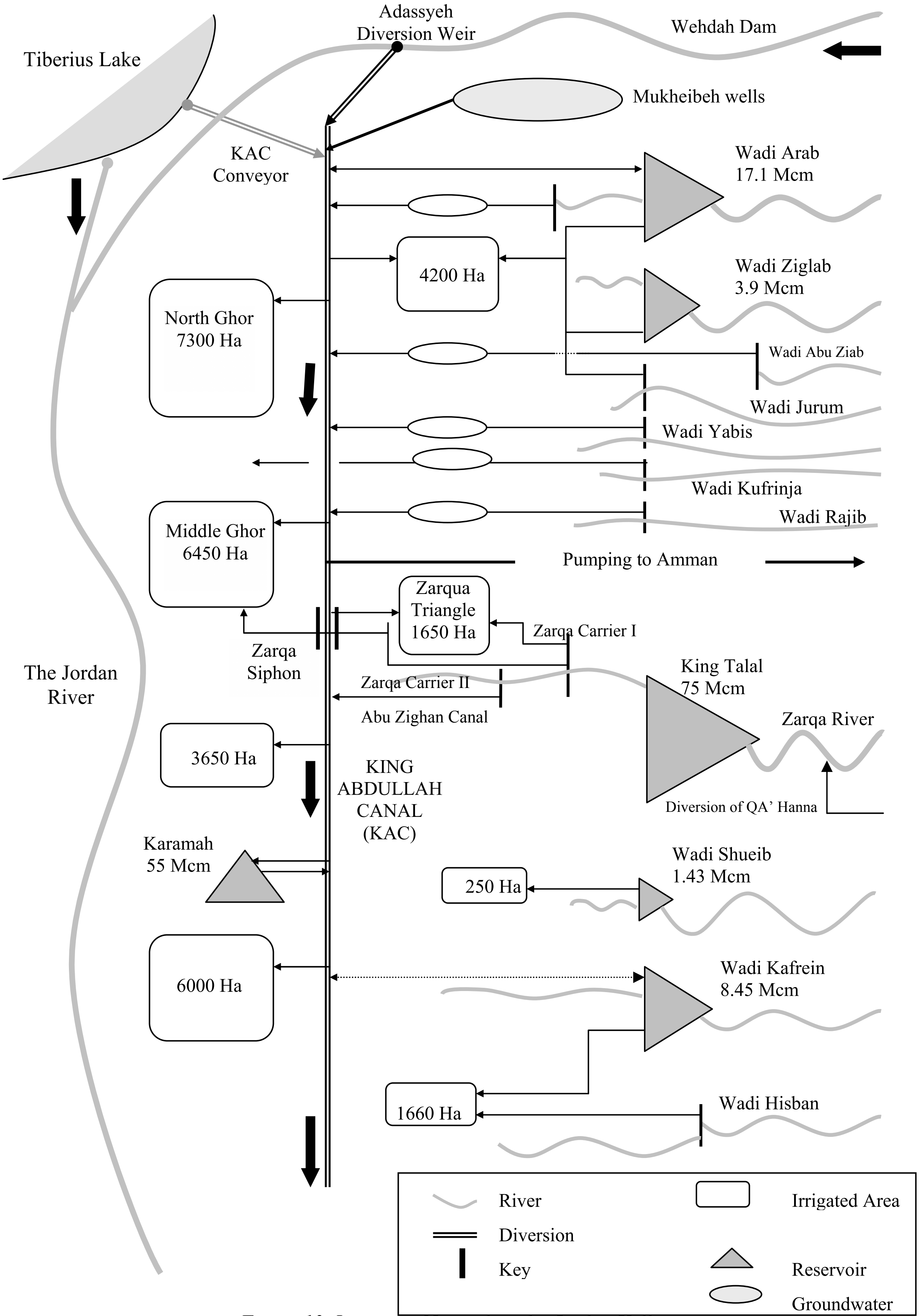


Figure 13. Irrigation Network in the Jordan Valley

- The extreme north of the Valley[49]: A Citrus and bananas zone.

In this area, the land is cultivated since the beginning of the century. Large Jordanian families (the Ghazawi and Al Waked families) irrigated the land thanks to wells and thanks to water from the Yarmouk. Bananas and vegetables were the main cultures. Citrus, pomegranate trees and cereals were also cultivated but on smaller surfaces. The construction of the first section of the King Abdullah Canal from 1958 to 1968 as well as the land reform of 1962 (cf. part III) have modified both the land tenure and the land reclamation. One share of the land has been nationalized (especially plots cropped by foreigners within the area) and re-allocated by unit ofs 30 to 35 dunums to former sharecroppers and agricultural workers or to Jordanian families from Irbid or Amman[50]. On another hand, the Ghazawi and the Al Waked families managed to keep their land (and even to expand it) by redistributing their plots between their sons and daughters before the enacting of the land reform process. Surfaces planted with vegetables have newly and quickly been planted with Citrus (mandarin, clementine and lemon) and from the early 1970s most of the surface was planted with trees. On clayey soils bananas trees have been replaced by Citrus during the seventies. During the eighties new cultures appeared but stayed really limited because farmers think the market is better for citrus than for other trees.

Picture 4. The extreme north of the valley

(Source: MREA, 2002)

In these conditions there is an historical background which can explain the repartition of crops in the extreme north of the valley: Citrus and other fruits trees have been early planted in an area where there was no big scarcity of water and where the soil was good. The "water regulations" implemented at the end of the eighties by the JVA froze the water rights of the farmers according to the crops they had as the law's date. Actually, the JVA decided to limit new plantations of Citrus and Bananas by cutting back the allocation of water to 2 mm per day of irrigation and per dunum of cropped area for all the plots which were not cropped with trees at the date of the law (1990). The expansion of citrus orchards slowed down but the former surfaces planted with trees stayed because they were not concerned by this regulation. In January 2004, while the tendency is to decrease the agricultural water consumption, the JVA decided to 'legalize' the citrus orchards planted before the year 2001. It means that added to the old orchards planted before 1990 which were already receiving 4mm/day/du, orchards planted between 1990 and 2001 receive now the same amount of water. Old bananas orchards (planted before 1990) receive 8 mm/day/du while vegetables receive the basis allocation of 2 mm/day/dunum[51].

[49] Historical data are drawn from *Bourdin (1999)* and *Nims (2001)*

[50] It is worth noticing that in this area, the Palestinian refugees of 1948 have not beneficiated of the land reform mainly because if the bought plots, they lost their refugee status what they did not want (*Nims, 2001*).

[51] Water rights and water allocations will be presented in further details in the following sections of this paper.

- <u>The area located around the villages of Wadi Ryan and Kreymeh: A landscape of vegetables in open field.</u>

Picture 5. Open field landscape in the north of the Valley (Source: MREA, 2004)

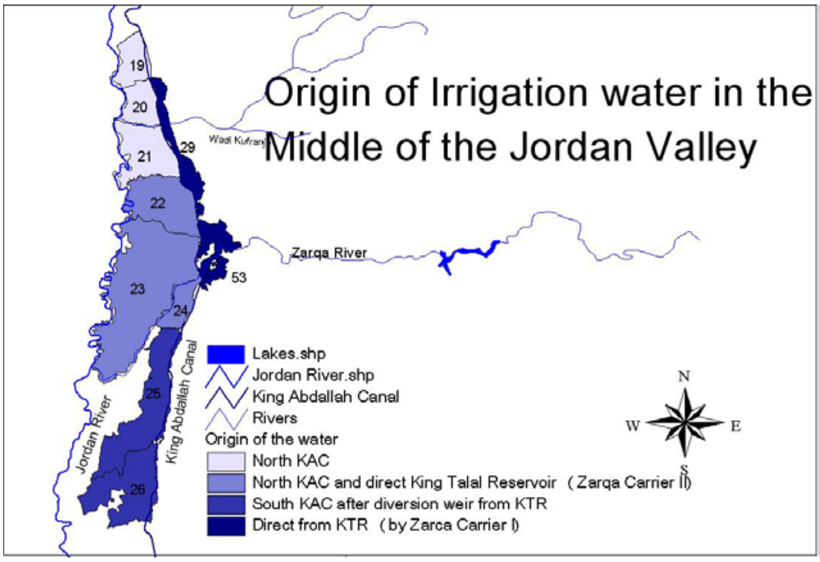
In this area, we can find a large numbers of farmers originating from the West Bank (Al-Zeinati and Al Turkman families) and who moved into the Jordanian Side of the Jordan Valley in 1948. They have beneficiated from the land reform and, at this time, head of families were granted small plots of about 50 dunums (*Nims, 2001*).

The expansion of citrus orchards reached this area later than in the extreme north of the valley (mid to end of the eighties) and has been strongly slowed down by the regulation enforced by the JVA (Cf. above). Citrus are thus really limited in this zone where most of the surface is cropped with vegetables in open field, wheat and olives. On another side, greenhouses stay rare because of climatic conditions which do not allow initiating the production early enough and to extend it in a significant manner to have significant advantages thanks to counter-season prices. Repercussions on the Net Profit of farmers are not important enough to counterbalance the needed investments to have some greenhouses (initial investment and operational costs). This point has however to be balanced since the process of farming intensification is still running. Actually, in the Jordan Valley, the number of greenhouses is increasing while the average surface of the farms is decreasing. If historically the first greenhouses appear in the middle of the valley (as we will see in the following paragraph), they are now slowly spreading to the north: few farmers (the more intensive and technical one) began to use greenhouses to crop high-return crops (strawberries, beans, sweet pepper…)[52]

(iii) The Middle Valley

- <u>Water considerations (cf box on the following page)</u>

Figure 14. Origin of the Irrigation Water used in the middle Valley



Within the Middle of the Jordan Valley, the agricultural water supply is more complicated than in the north of the valley. In the north, all (or almost all) the irrigated perimeters are directly receiving pressurized water from the pumping stations supplied by the King Abdallah Canal (KAC)

[52] There is around 10% of the area which is cropped under greenhouses.

Box 3. Note on Impact of Water Quality on Agriculture and irrigated farming systems in the Jordan Valley

One of the scenarios we will focus on and we will try to quantify in the following sections of this paper is the possible shift from freshwater to treated waste water in the north of the valley. Due to the present water crisis it is actually possible that all the Jordan Valley will be supplied by treated waste water and that freshwater from the Yarmouk River will be re-allocated to domestic uses mainly in Amman. In that perspective, lessons can be drawn from the shift which has already occurred in the middle of the valley at the end of the 1980s /beginning of the 1990s when this area has been supplied with water coming from the King Talal Reservoir (KTR). When the shift occurred in the middle valley and when the network had been completely pressurized (1995-1996), some farmers fled the area of the Zarqa Triangle (area directly supplied thanks to the Zarqa Carrier coming from the KTR) and went to the north. This led to an increase of land rent costs in the north (area of Kreymeh). Some non-objective reasons can be found to explain this movement (fear of the new conditions and ignorance of the consequences treated waste water could have) but there are also some objective reasons and technical justification since 1995-1996 corresponds also to the period when the salinity of the water coming from the KTR and used in agriculture in the middle of the valley strongly increased because the effluent of the As-Samra treatment plant began to represent more than one third of the influent of the KTR[53]. Other farmers stayed within the area and attendant measures have been taken to favour the acceptance of treated waste water. These measures have mainly consisted in a higher quantity of supplied water[54].

Through the surveys we have realized in the middle of the valley we have seen that there are no big differences in farming systems between areas where treated waste water is used in agriculture and others where freshwater is supplied to the perimeters. The quality of water does not appear as a parameter determining the kind of production system developed by the farmers[55] (the capacity to invest is, for example, more important in the definition of the farming systems). This has several reasons.

The first one is the fact that the drip irrigation is a well adapted system to the agricultural use of treated waste water (slight risks of contamination). By applying water only in the share of the soil explored by roots, the drip irrigation leads to form a bulb causing salts accumulation outside the roots area an allow reclaiming treated waste water with high salt contents. To avoid high salts concentration spots, it is however needed to regularly leach the soil (*Massena, 2001*). The use of treated waste water in drip irrigation has however some drawbacks and notably the filters and emitters clogging (due to organic solids and above all to an important concentration of algae in the water used) but soften the impacts of treated waste water on crops and soils.

The second explanation is linked to the fact that farmers who receive treated waste water receive more water in summer than the one supplied with freshwater. Actually, since several years, the water allocations are reduced[56] in summer for farmers receiving water from the King Abdullah Canal (KAC) while farmers supplied by the Zarqa Carriers conserve their allocation even in summer[57]. The quantity of water could counterbalance the lower quality of water and soften the differences between farms and farmers receiving fresh or treated waste water.

Nevertheless, the water quality has some slight impacts on farming systems and some slight differences can be identified between the areas supplied by treated waster water and the ones receiving freshwater. Therefore, in the landscapes of the middle valley, there are less greenhouses of cucumber when going southwards (according to the FAO, cucumbers are more sensible to salts than tomatoes). Moreover, farmers receiving water from Zarqa Carrier do not beneficiate of the filtration and of the sediment deposit occurring in the pumping station of the KAC, the water they receive is thus more loaded. When water is supplied, they thus need to let it stay more time in their pools, in order to let the water load settle[58]. That reduce their liberty to adapt the irrigation schedule to the crop requirements and a closer management is thus needed to counterbalance this disadvantage. Finally, the impact of the treated waste water used in the Jordan Valley is slight on classic and common crops (Tomato, zucchini, cucumber…) but on another hand, it is impossible to crop sensible crops such as strawberries, beans or other high value crops with such water. According to these field observations, we will try in a following section of this paper to quantify the impacts of the generalization of treated waste water use in the Jordan Valley.

[53] The volume of the As-Samra plant's effluent increased in the middle of the 1990s because of the development of Amman which follows the Palestinian migration after the first gulf war, in the same time the Zarqa River flow strongly decreased, that leads to a water salinity increase in the KTR. Please refer to chapter II to have more information on the evolution of the Zarqa River flow.

[54] The well-founded of such measures increasing the supply of salty water to farmers could be discussed and further studies would be needed on this point.

[55] As the reader could see it in the following section of this paper, we never have considered it in our modelling

[56] Allocations have been reduced of 25% in 1999, 2002, 2003 and 2004 of 30% in 2000 and of 50% in 2001 due to shortages of water in summer.

[57] It seems also that the JVA grants extra hours of water more easily to the farmers who are supplied with treated waste water that to the ones who receive fresh water. They thus can better meet the crops requirement. We do not enter into details here but the precise aspects of water management in the Jordan Valley will be tackled in a following section of the report.

[58] Pools have to be cleaned every year, while it is possible to clean it every two years when it is filled with freshwater coming from the northern part of the KAC.

The map above, clearly show that in the middle of the valley, the situation is more complex. Four different situations can actually be described:

- Firstly, in the north of the Zone, irrigated perimeters are, like in the north of the valley, supplied through a pressurized network linked to the King Abdallah Canal and thus receive freshwater (DA[59] 19 to 21).

- In DA 29 and 53, the irrigated perimeters (1.650 ha, designate as the *Zarqa Triangle* –cf. Picture on the previous page), located easterly of the KAC, receive water directly coming from the King Talal Reservoir (KTR) to their Farm Turnout Assembly (FTA) thanks to a pressurized pipe (the Zarqa Carrier I). This water is a 1:1 ratio-mixed-water between freshwater of the Zarqa River and treated waste water from the treatment plants of Amman and other cities. The blending is done in the King Talal Reservoir located in the *Highlands*, on the Zarqa River.

- In the DA 22, 23 and 24. Two situations exist. Some of the perimeters receive fresh water coming from the northern part of the KAC, other perimeters receive mixed water coming directly from the KTR thanks to another pressurized pipe: the Zarqa Carrier II.
- Finally, in the village of Deir Allah (cf. map above), another pipeline (open at its end) coming from the King Talal Reservoir joins the KAC through the Abu Zighan Canal. Northwards of this junction, irrigated perimeters supplied through the KAC[60] receive fresh water (like in the north of the valley) while perimeters located in the south of Deir Allah receive, through the KAC, a mix between water coming from the northern part of the KAC and from the King Talal Reservoir[61]. Concerning the agricultural zoning we have divided the middle Valley in two different areas:

- <u>A first zone centralized around Deir Allah</u>

It lies from the village of Kreymeh in the North to the village of Al-Arda in the South. If, for more clarity we will describe the farming systems within this global area, we can say that there are two sub-regions: the one located in the north of Deir Allah and the one in the south of this village. These two areas differ by the repartition of the farming systems (there are more greenhouses in the North than in the South of Deir Alla) but on a global point of view around 70% of the surface is cropped under greenhouses[62].

Picture 6. General landscape of the Middle valley: A greenhouses area (Source: MREA, 2004)

[59] DA is used for Development Area.

[60] In this area, we have seen before that some of the perimeters receive water directly coming from the KTR thanks to the two Zarqa Carriers.

[61] It is worth knowing that the water quality in the Zarqa Carriers I and II and within the KAC southwards of Deir Allah is quite the same. Actually at the junction between the KAC and the Abu Zighan Canal coming from the KTR, the remaining freshwater from the Yarmouk in the KAC is negligible, the blended ratio thus remains 1:1. However concerning on farm irrigation, the water quality is not the same, since the farms irrigated thanks to water coming from the KAC benefits from an additional sedimentation in the Canal and above all from additional filtration in the pumping stations managed by the JVA, two advantages that farmers receiving water directly from the Zarqa Carriers do not have. The box besides present the

[62] In the south of Deir Alla we can find 50% of greenhouses, 40% of vegetables in open field and 10% of citrus, in the north there are 70% of greenhouses, 20% of open field and 10% of citrus.

Deir Allah constitutes the village from where the greenhouses historically have been developed in Jordan. From Deir Allah and both to the south and to the north, we can observed a lessening gradient concerning the greenhouses density. Despite the knowledge of the different processes occurring in the valley, we do not have a clear idea to explain this gradient. Several hypotheses can actually be proposed. The favorable climatic conditions[63], the existence of good quality soils (cf. soil description above), a longer agricultural history than in other parts of the valley[64] and the fact that Deir Allah is located at the end of what has been the first section of the canal (finished in 1966)[65] could therefore explain that the greenhouses have been previously developed in the neighboring of this village than in any other parts of the valley.

Greenhouses are found both in the south and in the north of the village of Deir Allah[66]. Their density is however higher northwards than southwards. Several explanations can be presented: irrigated agriculture has been firstly developed in the north (before 1978 there were no canal in the south[67] while a regular water supply existed in the north thanks to the KAC), by the soil quality and now by the water quality (both better in the north than in the south).

- The second region stretches over between the villages of Al-Arda and Karameh

This area can be divided, from the north to the south, into three sub-regions:

- From the villages of Al-Arda to Ar-Ramil large farms can be found. These farms are owned by important owners or institutions like the Ministry of Agriculture, the University of Jordan and some princes of the royal family. These farms are mainly planted with citrus or palm trees (even prickly pears) and constitute 70% of the surface in this area. In this area the last examples of large vegetables farms under greenhouses can also be found.

[63] It is colder in the north and hotter in the south, what implies that the production under greenhouses is not enough bring forward -or moved back- to insure the necessary economic return to counterbalance the investment linked to this cropping method.
[64] A village has always existed in this area maybe because the plain is larger than elsewhere and because of the existence of several *side wadis* supplying water for domestic, pastoral and agricultural uses.
[65] This last explanation is dictated to us by some present observations. Actually, at the end of the canal now managed by the JVA, farmers have the right to pump directly into the canal. It is justified by the fact that after the water flows uncontrolled and thus is 'lost' for agriculture. Farmers pay a fixed-low-fee and they can pump water as much as they want. We can think that the situation was the same two decades ago in Deir Alla, when the canal was not finished. This excess of water could be one of the explanations for the greenhouses development since vegetables under greenhouses require more water than in open field.
[66] It implies that the quality of the water (better in the north, cf. zoning above) is not a determining factor to *"the presence or the absence of the greenhouses"*. Other characteristics, as the capacity of investment, are preponderant to determine the existence or the absence of greenhouses in a farm.
[67] Irrigation was still dependant on springs and *wadis*' flows.

- From the villages of Ar-Ramil to Karamah, small vegetables farms in open field can be found managed by Jordanian, Palestinian and Pakistani families. The size of the farm is included between one to four units (35 to 120 dunums).

- A particular area can be identified around the village of Karamah. Added to the 'classic' small vegetables farms in open field, we can also find farmers cropping mint and parsley in open field. That is linked to the peculiar conditions regarding the access to water resources. Actually, there are several private wells in the neighbouring of the village[68] and on another hand; farmers are allowed to pump directly into the canal. It is due to the fact that Karamah is located at the end of the canal presently managed by the JVA. After this point, the water flows uncontrolled during winter and is 'lost' for the public irrigation network.

(iv) The Southern Valley

This area lies between the village of Karamah and the shores of the Dead Sea, it is a relatively large area (9 to 12 km) but due to salty soils, unfit for agriculture, and to the absence of any irrigation network, the irrigated perimeters are not much extended and located near the mountains (cf. the map presented above).

- Water considerations and zoning

We have divided the Southern Valley into two sub-regions depending on the water supply. In these areas, there isn't any pressurized water-supply-network as the one managed by the JVA in the north and the middle of the valley and it is common to see some private pipes running along the road from the source of water to the farms (cf picture besides).

The southern Valley area correspond to the *"14,5 km-irrigation project"* area. It is the last section of the canal finished in 1988 and which is still not in use. In winter, the extra-water reaching the village of Karamah and the end of the functioning concrete canal (KAC) flows without any control in the 14,5km-section while in summer gates are closed in Karamah and no water flows within the last section of the KAC. Two areas can be distinguished:

- The first one in the north is irrigated thanks to the water coming from the Shueib dam. This one flows in open concrete channels. This water is free of charge and each farm **OWNS** a share of this water[69]. In winter, farmers pump also directly into the 14,5-km-section of the KAC. In this area, we can find a little numbers of vegetables farms in open field (or under greenhouses) and a lot of bananas farms.

- The second area in the extreme south of the valley is irrigated thanks to the Kafrein reservoir and to the Hisban non-controlled *Wadi*. This irrigated area is known under the name: "*Hisban-Kafrein triangle*". The water used is charged at the same fee that in other places in the Jordan valley (0.015 JD/m^3). Water in the canal does not reach this area even in winter.

Added to the water coming from reservoirs or *wadis*, most of the farmers in the area have another source of water: some owns a well[70], others buy water to well's owner[71]. Water pumped from wells has a lower quality than the one coming from *wadis* and reservoirs, thus all the farmers -if they do not own a desalinization plant in their farm[72]- mixed their water into a pool before using it.

[68] These ones were historically used to irrigate mint and Parsley within the village
[69] According to traditional rights of water and simplifying: *'who owns the land owns the water'*
[70] With Azraq, the south of the valley is the area where an important number of illegal wells can be found.
[71] By tanker or by pumping directly in the well
[72] It is the case of the most large, intensive bananas farmers

Picture 7. "off-farm" irrigation network in the southern Jordan Valley (Source: MREA, 2003)

Despite the public supply of water (mainly from *Hisban Wadi* and *Kafrein reservoir*), most of the farmers do not pay their water bills. Moreover, they, almost all, own pipes and a true "off-farm" irrigation network to take the water where it is located (*Wadis*, channels… cf. picture above). The farmers feel free to do what they want regarding the water supply according to their financial means.

- Some words on history

Picture 8. Bananas Landscape in the south of the valley (Source: MREA, 2003)

This peculiar situation regarding water supply in the *Hisban-Kafrein triangle* can be explained thanks to a rapid socio-historical presentation of the area. The land is owned by members of the large Al-Adwan Bedouin family who settled down in the area during the Ottoman Empire by purchasing big plots of land. Added to livestock farming they always have reclaimed some irrigated plots along the permanent *Side Wadis* and since the 1960s, they have develop some bananas plantation thanks to the water coming from *wadis* and wells. This peculiar history explains the permanence of the tribal rules to manage the irrigation.

During the 1980s, the JVA implemented several irrigation projects (dams) in order to control the flow of the permanent *Wadis*. The institution tried to implement and to manage an organized water-supply network which addressed –and continue to address today- the reluctance of farmers in the area. Actually, the farmers do not understand why they should pay for a resource they already own, according to their local laws. Moreover there is already a network, locally managed and they do neither need nor want the government to be involved in such action of management.

III.3.3 The Highlands

'*The Highlands'* is a generic name to refer to the entire Jordan, Jordan Valley excluded. We use it here to designate the Lower Jordan River Basin, Jordan Valley excluded. It can be divided into six sub-regions: the *Eastern Desert* or *Badia,* the U*pper Yarmouk Basin*, the *Zarqa River Area*, the *Uplands Area*, the S*uburban Area* and a T*ransition Area*[73]. Please refer to the map presented above and the two tables below presenting the repartition of the irrigated areas both in each groundwater basin and in each *agricultural zone.*

Irrigated Surfaces within the Highlands of the Lower Jordan River Basin								
Surface in dunums	Side Wadi Basin		Amman-Zarqa Basin		Upper Yarmouk Basin		**Total**	
	Surface	%	surface	%	surface	%	**surface**	%
Annual Crops	34 758	85,5	33202	23,1	7255	14,7	**75 215**	32,2
Deciduous trees	1 819	4,5	37795	26,3	24423	49,5	**64 037**	27,4
Non-deciduous trees (mainly olive trees)	4 064	10,0	72535	50,5	17670	35,8	**94 269**	40,4
Total	**40 641**	100	**143532**	100	**49348**	100	**233 521**	100

Irrigated Surfaces within the Highlands of the Lower Jordan River Basin											
Surfaces in dunums		**Annual Crops**			**Deciduous trees (in which)**					**Non-deciduous trees**[74]	**Total**
		Cereals	**Veg**	**Total**	**Peaches/ nectarines**	**Apples**	**Grapes**	**Others**	**Total**		
Eastern Desert Area	surface	1607	21962	23569	18782	15808	3130	15652	53373	79787	**156729**
	%	1,0	14,0	15,0	12,0	10,1	2,0	10,0	34,1	50,9	100
Zarqa River Area	surface	-	2839	2839	1175	1007	168	1007	3357	8075	**14271**
	%	-	19,9	19,9	8,2	7,1	1,2	7,1	23,5	56,6	100
Upper Yarmouk Area	surface	-	7164	7164	-	-	-	-	-	-	**7164**
	%	-	100,0	100,0	-	-	-	-	-	-	100
Transition Area	surface	-	720	720	2004	1687	334	1670	5695	2065	**8480**
	%	-	8,5	8,5	23,6	19,9	3,9	19,7	67,2	24,4	100
Uplands Area	surface	-	39899	39899	41	82	204	-	326	199	**40424**
	%	-	98,7	98,7	0,1	0,2	0,5	-	0,8	0,5	100
Suburban Area	surface	-	597	597	2467	822	822	1371	5483	360	**6440**
	%	-	9,3	9,3	38,3	12,8	12,8	21,3	85,1	5,6	100
Total	surface	**1607**	**73181**	**74788**	**24469**	**19406**	**4658**	**19700**	**68234**	**90486**	**233508**
	%	**0,7**	**31,3**	**32,0**	**10,5**	**8,3**	**2,0**	**8,4**	**29,2**	**38,8**	**100**

Table 9. Repartition of the Irrigated Areas in the Highlands of the Lower Jordan River Basin in Jordan[75]
(Please note that 1 ha=10 dunums)

[73] This latest region is intermediate between the uplands and the eastern desert.
[74] Mainly olive trees
[75] For the Amman-Zarqa Basin, and the Eastern desert area, the evaluations of the irrigated areas have been done, for several reasons, according to *Venot (2004).* Please refer to this reference for further information concerning the problems raised up by an evaluation of the irrigated surfaces. The other figures are drawn from the GIS-landuse analysis.

Two kinds of 'agriculture' can be described:

- ✓ An ancient one, developed along permanent *Side Wadis* thanks to springs and shallow wells in the *Zarqa River* and in the *Uplands areas.*
- ✓ A more recent one developed in the 1970 and 1980s thanks to deep wells in the *Eastern Desert Area*. Moreover we will see that during the 1990s a redistribution of the agriculture occurs within the *Highlands.* From the neighboring of Amman, farmers fled to more distant areas where water was less expensive.

(i) The Eastern Desert or Badia (cf. Pictures besides)

In the *Eastern Deserts*, some governmental projects aimed, since the 1960s, to settle Bedouins by irrigating some lands thanks to deep wells and to a network of concrete open channels both managed by the public institution in charge of water in the *Highlands* (the Water Authority of Jordan[76]). This has been the first incentive to develop the agriculture in the *Highlands*[77] which has been mostly developed after the mid 1970s, the real boom dating of the early 1980s. The two oil crisis (1973 & 1979) could be an explanation to this development: following the crisis, an expanding regional market for vegetables and fruits as well as a large amount of money became available. Palestinian and Jordanian working in the gulf took advantages of this phenomenon and could invest in different economic sectors. Moreover, during this period, new resources of water have been identified (groundwater resources), energy costs decreased and modern irrigation-and-cropping techniques (digging of well, drip irrigation, greenhouses…) became widely applicable while in the same time and thanks to the Oil Crisis an agricultural-export-market to the Gulf States has been developed. Therefore agriculture constituted one profitable sector in which the investments have been developed[78]. However agriculture in desert land has been expanded at the expense of the sustainability of the renewable water resources. The over abstraction of water by private and public sectors as well as the expansion of unplanned irrigated cultivable land are now threatening the water resources of Jordan.

In this area and in spite of desert conditions (low humidity, wind and dust) a modern vegetables-and-fruits irrigated agriculture has been developed. Several conditions were brought together: low water and land costs, fertile and not infected[79] soils easy to reclaim (tractor, plough…), no theft of production, and no direct consequences of pollution for the farmer since this one can easily change the plots he crops in this raw desert land where there is no pressure on the land.

Added to this first "wave" of agricultural development, we can identify a second wave which took place in the mid of the 1990s. This wave consists in a *'redistribution'* of the farms within the *Highlands*. A lot of farmers who were cropping in the surroundings of Amman set up in the *Eastern Desert* at this period because of lower water prices.

Actually, following the increasing urban pressure of Amman due to the return of Palestinian-Jordanian from the gulf countries after the first Gulf war of 1991, the agricultural water prices in the surroundings of Amman increased. This is linked to the peculiar water tenure in the area. In most of the cases, farmers do not have a well and buy their water. As the owners of wells supply both the city and the farmers, the agricultural water prices are dictated by the domestic prices. Until 2002, water pumped from private wells for domestic purposes was sold at 0,250 JD/m^3 (0,35 \$/m^3), agricultural water too. Since then, an additional governmental fee of 0,250 JD/ m^3 has to be paid. The price of domestic water pumped from wells increased by such as much as well as the price of water sold for agricultural purposes. The prices are thus higher than everywhere in the country: they are about 0,5JD/m^3 (0,7 \$/m^3) while fees paid in the Jordan Valley to the JVA only reach, on average, 0,015 JD/m^3 (0,02 \$/m^3) and effective costs of water in the eastern desert are included between 0.065 and 0.120 JD/m^3 (0.09 to 0.168 \$/m^3).

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[76] It is the equivalent of the JVA in the whole country-Jordan Valley excluded.

[77] If the large public-managed projects seem to have failed in most of the case, a lot of Bedouins have drilled their own wells and settled to irrigate their land, keeping one part of their herd.

[78] Moreover, loans of the World Bank could allow some people to invest at preferential rate (7%).

[79] There is no trace of fungus, nematodes or bacteria

Picture 9. Diverse landscapes of the Eastern Deserts
(Source: MREA, 2003)

According to the general table presented above, the total irrigated surfaces in the *Eastern Deserts* reaches appreciatively 156.729 dunums, of which 51% are olive trees, 34 % deciduous trees (stone fruit trees: peach and nectarine trees essentially) and 15% annual crops.

(ii) Upper Yarmouk Area

Upper Yarmouk Area
(Source: MREA, 2003)

This area, mainly characterized by a Mediterranean rainfed landscape, has been newly colonized by agriculture, following the last process described above (displacement from the suburban area to other areas). As in the *Eastern Deserts*, farms are organized around wells pumping groundwater. The general table above shows us that we can only find vegetables farmers in this area. Farmers concerned, often reclaim their land during summer and have another farm they cropped during the winter in the Jordan Valley

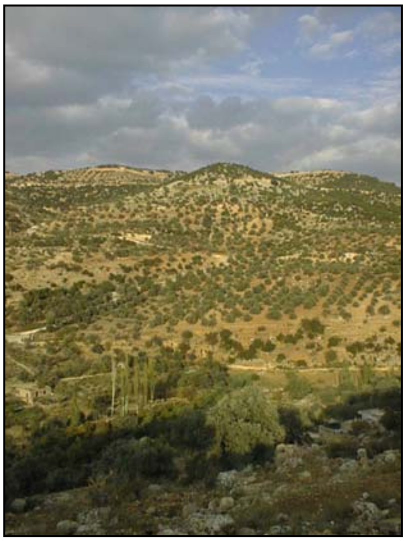
(iii)The Zarqa River Area

Picture 11. The Zarqa River
(Source: MREA, 2003)

The Zarqa River is the most important of the *Sides Wadis* incising the mountains. As we have said before, it is along these permanent *side wadis* that the first signs of irrigation appears in Jordan thanks to hand made techniques allowing irrigating crops during the summer (diversion weirs, earth ditches…). Most of the farms located along the Zarqa River are irrigated thanks to shallow wells or to direct pumping in the River[80]. We can see that olive is the most important crop in this area (57% of the total irrigated surface), vegetables (and fodder) represent 20%. Other trees represent 23% of the surfaces. This evaluation of the irrigated surfaces seems to us to well depict the reality.

(iv) Uplands Area

Picture 12. General landscape of the Uplands in The Lower Jordan River Basin in Jordan
(Source: MREA, 2003)



It is a mountainous area and most of the agriculture is rainfed. The major crop is rainfed olives tree. However, some irrigated area exists. They are located along the banks of some little rivers or near natural springs. Most of the irrigated farms we saw were located near the cities of the area. We only have studied the fruit and vegetables farms, but it has to be mentioned that small horticultural farms can be found. It is worth noticing that because of less water available and less profitability of the agriculture sector, irrigated surfaces seem to be decreasing within the uplands since the end of the 1980s, beginning of the 1990s.

In the evaluation presented above, trees represent 2 % of the irrigated area while vegetables represent 98% of the surfaces. In our mind, the irrigated surfaces planted with trees have been highly underestimated since there are a lot of small plots of trees located along the *Side Wadis* incising the mountains which are irrigated thanks to water flowing into earth channels and which do not seems to be considered as irrigated here[81]. In addition, we can say that these trees are very diverse (Figs, almonds, Apricots, pomegranates…)

[80] This last way of irrigation (direct pumping into the river) stays limited to fodder farms due to the low quality of the water flowing into the Zarqa River. This one is actually a mix between freshwater and low-quality treated waste water flowing from the Khirbet As Samra plant treating the waste water from Amman.
[81] We have said before, the surfaces have been evaluated thanks to a GIS-landuse analysis drawn from an interpretation of two satellites maps. This can explain the underestimation of irrigated surfaces of trees in this area where vegetation is quite abundant. It is actually difficult to differentiate irrigated and rainfed trees especially when small plots are concerned.

(v) The suburban Area


Picture 13. The Suburban Area
(Source: MREA, 2003)

In this area, a lot of horticultural farms can be found[82], especially because of the proximity of the consumption centres. The evaluation of the irrigated surfaces presented **above does not seem to be accurate** since an important agricultural activity based on vegetables in open field and under greenhouses exists in this area and does not appear within the GIS-analysis. As we said before, farming systems in the area are characterized by their high water costs.

(vi) The transition area

Picture 14. The Transition Area
(Source: MREA, 2003)

This *transition area* is intermediate between the *Eastern Deserts* and the *uplands*. There is 92% of trees (mainly olives) and 8% of vegetables. This evaluation seems to us to be accurate and to relatively well depict the reality even if the effective surfaces of irrigated annual crops should be a little bit higher. It is an area where rainfed cereals (Wheat and Barley) mainly planted by herders, because of adapted climatic conditions, still persist and even dominate the landscape.

[82] We will not present these peculiar farming systems and will focus ourselves on the fruits and vegetables activity which constitute the main agricultural activity of the Lower Jordan River Basin (both in terms of surfaces and number of farmers)