Food and Agriculture
Organization of the
United Nations

Syrian Arab Republic

Capitalization of the rehabilitation of Al-Rastan irrigation network study

Smallholder support programme

Funded by
the European Union

Syrian Arab Republic

Capitalization of the rehabilitation of Al-Rastan irrigation network study

Smallholder support programme

Food and Agriculture Organization of the United Nations
Rome, 2023

REQUIRED CITATION

FAO. 2023. *Syrian Arab Republic: Capitalization of the rehabilitation of Al-Rastan irrigation network study – Smallholder support programme.* Rome. https://doi.org/10.4060/cc6741en

ISBN 978-92-5-137972-1

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of FAO and do not necessarily reflect the views of the European Union.

Contents

Figures

Tables

Acknowledgements

This document presents the results of a capitalization study of an irrigation network in Al-Rastan, Homs governorate in the Syrian Arab Republic, rehabilitated by the Food and Agriculture Organization of the United Nations (FAO) with funds provided by the European Union, under a project managed by Alfredo Impiglia, Chief Technical Advisor, FAO.

The study is a result of collective efforts from the FAO water team in the Syrian Arab Republic and under the overall supervision of Mike Robson, FAO Representative in the Syrian Arab Republic and the technical guidance of Mr Wael Seif, Team Leader.

Authors are acknowledged for their contributions in various fields of expertise: Wael Seif, Khaled Haider and Lubna Jareaa, as well as members of the water team for their support: Ameel Shadoud, Janet AlKanani, Taghreed AlSaleh, Yaser Ahmado, Elias Sulaiman and Riham Zahalan.

Thanks are due to Jean-Marc Faurès, Regional Programme Leader at FAO Regional Office for the Near East and North Africa and Mike Robson who provided inputs on the methodology for this study, as well as Alfredo Impiglia, Feras Youssef and Rosa Jarary for their constructive comments and reviews.

FAO acknowledges the support of the European Union for funding the project and this specific study which reflects the impact of the Al-Rastan irrigation project on agriculture, natural resources and livelihoods, and paves the way for applying similar methods to the impact assessment of other irrigation projects.

Special thanks go to Vittorio Cagnolati from the Delegation of the European Union to Lebanon (EEAS-Beirut) for his feedback, review and related discussions throughout the development of this study.

Finally, thanks are also due to the consulted stakeholders and farmers for the information they provided during the study, and to their underlying commitment to restoring profitable irrigated agriculture in Al-Rastan.

Abbreviations and acronyms

BCR	benefit–cost ratio
FAO	Food and Agriculture Organization of the United Nations
FCS	food consumption score
GM	gross margin
NDMI	Normalized Difference Moisture Index
NDVI	Normalized Difference Vegetation Index
TR	total revenue
TVC	total variable cost
SPSS	Statistical Package for Social Sciences
SYP	Syrian pound
WaPOR	FAO portal to monitor water productivity through open access of remotely sensed derived data
WUA	water users' association

Executive summary

The northern part of the Homs-Hama irrigation network in the Syrian Arab Republic was rehabilitated by the Food and Agriculture Organization of the United Nations (FAO) under the European Union-funded smallholder support programme designed to support agricultural productivity and sustainable use of water resources.

Led by FAO, the comprehensive multidimensional capitalization study aimed at reviewing the achievements of the rehabilitation of the irrigation project at different levels. This included comparing these achievements against plans, and assessing the impacts of the rehabilitation of the irrigation network in Al-Rastan on agriculture, natural resources and socioeconomic status of the targeted communities. Moreover, the study's results help identify further pathways for improving the performance of irrigation management and sustaining natural resources while strengthening the resilience of smallholder farmers.

Data collection methods included individual household interviews through a stratified sample of 401 farming households; focus group discussions with representatives from the local community, key informants and experts; ground-based data for surface and groundwater; and remote sensing derived data. This was followed by data analyses that included remote sensing techniques using Google Earth Engine and FAO portal to monitor water productivity (WaPOR), Statistical Package for Social Science and laboratory tests for water quality.

Opening access to irrigation water for about 11 000 ha of irrigable area contributed to increased cultivated areas. Summer cultivated areas increased from about 687 ha in 2018 to about 5 180 ha in 2021 (from about 3.7 percent to 28 percent of the total area) while winter cultivated crops increased from 1 962 ha in 2018 to 5 713 ha in 2021 – almost the same as in 2010.

During the field study, visited farmers in the targeted villages confirmed summer crops area increased from 808 to 1 539 ha and cultivated areas of other crops increased from 547 to 1 754 ha between 2020 and 2021. They also confirmed an increase in winter crops area from 6 406 to 8 470 ha between the two years.

At the sample level, total cultivated area has increased by 13.8 percent with an increase in irrigated area by 229 percent. Livestock numbers at the sample level have also increased by 22 percent, 29 percent and 25 percent for cattle, sheep, and goats respectively.

The socioeconomic study of the households' sample indicated a significant relationship between access to irrigation water and both, income generated from the agricultural land and food security status represented by the food consumption score. Furthermore, the number of returnees among internally displaced persons was 4 108 households (about 24 650 persons), which indicated improvement in the stability of local communities after the rehabilitation of the irrigation network and the restoration of agricultural production – the main source of livelihood.

The resumed agricultural activities in the study area provided employment opportunities for the local communities and revived local market activities. Nevertheless, some challenges remained, particularly the constant rise in the prices of agricultural inputs and fuel which did not match the increase in prices of agricultural products.

The cost analysis of the intervention revealed that the benefits outweighed the costs with a return on investment at around 750 percent which indicates high profitability and performance of the rehabilitated irrigation network.

In terms of natural resources, the study revealed that the groundwater level has increased by an average of 2 metres as a result of farmers using the surface irrigation network, especially for winter crops. Chemical analyses of surface and groundwater samples confirmed that the rehabilitation and the resumed agricultural activities had no adverse effects on water quality.

Environmental impacts of the rehabilitation were also assessed using remote sensing-derived data for the study area. The analysis of remote sensing data clearly showed a significant increase in the area cultivated not only with irrigated summer crops but also with winter crops (with supplementary irrigation) compared to the pre-rehabilitation period. Remote sensing further showed a positive impact on soil health (quality) and reduced land degradation, which was a concern in the area before rehabilitation.

The performance of the water users' associations (WUAs) was evaluated according to their commitment to fulfilling their roles in the implementation of proper irrigation schedules for the operation and maintenance of the irrigation network. The study shows that the six established WUAs (covering 1 523 ha) have been fairly performing their roles in the management of the irrigation system. They managed to maintain the irrigation canals within their areas of responsibility and were able to manage the distribution of irrigation water according to irrigation schedules with minimum to no conflicts or violations. Based on the Al-Rastan rehabilitation results, 16 new WUAs covering 4 475 ha are currently being established. Women's participation in the WUAs was limited due to several factors particularly social norms and land ownership. The project has taken some measures to encourage women's involvement and taking their role in the WUAs, namely, facilitating participation for women without proof of land ownership and enhancing their involvement in seasonal planning.

The main recommendations of the study include:

- continue to monitor and support the WUAs with further training;
- raise awareness and provide technical support;
- consider the application of modern and efficient irrigation techniques as part of climate smart agriculture practices to enhance water use efficiency;
- conduct a comprehensive study of the marketing channels;
- determine the challenges and opportunities to maximize the benefits of agricultural production for farmers;
- enhance the irrigation and agriculture extension units at the local level; and
- strengthen and empower the role of women in Al-Rastan rural areas and WUAs.

Context of the study

The rehabilitation of the northern part of the Homs-Hama irrigation network in the Syrian Arab Republic was implemented by the Food and Agriculture Organization of the United Nations (FAO) under the smallholder support programme funded by the European Union. Designed within the context of supporting agricultural productivity and sustainable use of water resources, the objective was to provide access to reliable and equitably managed irrigation water for smallholder farmers to increase agricultural production, and improve livelihoods and food security. The programme also supported the establishment of water users' associations (WUAs) and strengthened the capacity of farmers and technical staff in water resources and irrigation management. This was achieved through a participatory approach where farmers and technical staff were engaged in discussing related issues such as crop agenda, irrigation scheduling, operation and maintenance.

This comprehensive multidimensional capitalization study, led by FAO, reviewed the intervention's achievements on different levels, comparing these achievements against plans, and assessing the socioeconomic and environmental impacts of the rehabilitation of the irrigation network on natural resources and targeted communities.

The results and lessons learned from this study will help improve the performance of the irrigation management scheme while strengthening the resilience of smallholder farmers on this and other similar work to be implemented by FAO. The results also provide indications for updating the methodology and knowledge-based tools to further improve agricultural production and livelihoods while sustaining natural resources in targeted areas.

Objectives

The main objective of the study was to review the intervention's achievements at different levels (farming households, community, environment and natural resources), compare these achievements against plans and assess the impact of the rehabilitation on natural resources, agriculture and livelihoods.

The specific objectives were to study the:

- socioeconomic characteristics of the target communities using a representative sample of households;
- impact of the intervention on agricultural production and productivity;
- environmental impact of the intervention using an assessment of soil and water in terms of quality and quantity;
- performance of established WUAs and their role in irrigation management and fair distribution of water according to the agreed irrigation schedules; and
- irrigation management practices and their contribution to sustainability.

To this end, several indicators were used to review the intervention's impact (pre- and post-rehabilitation).

The results have drawn conclusions and proposed recommendations on future actions to enhance and improve the sustainability of natural resources and infrastructure for Al-Rastan and similar interventions.

Methodology

The study was conducted from March to May 2022 covering the 2021 cropping season, which was the first after rehabilitation that provided access to irrigation water. The study was conducted using both quantitative and qualitative methods namely household questionnaires, focus group discussions and key informant interviews, in addition to remote sensing techniques.

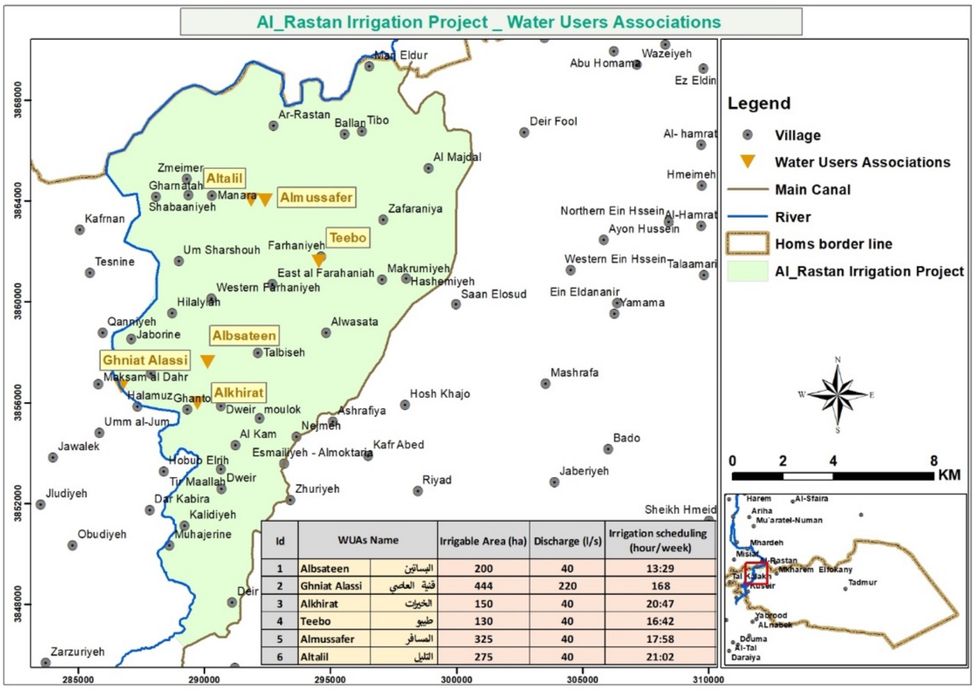
Interviews were conducted with a representative sample of beneficiaries in the target area, representatives of the six established WUAs, in addition to extensionists, representatives of local community and experts in agriculture and water resources. This was complemented by data analysis through remote sensing, economic and statistical methods. The economic analysis focused on direct and indirect costs borne by FAO to implement planned activities as well as the estimated benefits of the intervention.

The results, where possible, were compared to the situation prior to rehabilitation in terms of agricultural production and productivity, natural resources (availability, accessibility and quality) and basic socioeconomic status of the local communities.

Study area

The study was conducted within the target area of the irrigation rehabilitation intervention in Al-Rastan district as presented in Figure 1. This included 20 villages in Al-Rastan and Talbiseh subdistricts, Al-Rastan district, Homs governorate. Table 1 shows the distribution of households in each of the 20 villages and according to landholding size.

Figure 1. Rehabilitation project area in the Al-Rastan district



Source: Adapted from Google Earth Engine modified by the authors.

Table 1. Estimated number of households in the 20 villages of the target area and according to landholding size

No.	Village name	Area (donum)	Households	Households with less than 5 donums	Households with 5 to 15 donums	Households with more than 15 donums
1	Al-Rastan	56 500	9 980	1 996	6 487	1 497
2	Ghornata	5 000	1 190	7	82	117
3	Talibiseh	34 000	6 540	1 308	4 251	981
4	Al Ashrafieh	3 182	560	160	310	90
5	Al Najmeh	1 281	315	120	120	75
6	Dair Baalbeh	6 000	900	200	400	300
7	Al Mokhtarieh	1 188	675	450	100	10
8	East Farhanieh	1 440	448	90	291	67
9	Al Zafaraneh	2 000	778	155	505	118
10	Almkarmieh	6 100	600	120	390	90
11	Al Hashmieh	3 300	145	29	94	22
12	Al Ghanto	12 500	589	61	259	269
13	West Farhanieh	16 250	340	50	210	80
14	Om Sharshouh	5 525	450	140	200	110
15	Al Thawrah	400	120	75	30	15
16	Jaboureen	2 250	720	47	171	49
17	Al Khaledih	1 070	30	5	3	2
18	Al Dar Al Kabiereh	16 061	2 000	200	1 000	300
19	Al Dwair	3 195	300	200	35	22
20	Ter Maaleh	4 837	219	11	65	100
Total		182 079	26 899	5 424	15 003	4 314

Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

Data collection

Qualitative and quantitative data were collected through the following modality:

Individual household interviews

Collecting data at the household level allowed for studying the socioeconomic characteristics of the targeted community and capturing impact at the household level. Data were collected at the farm level as well to capture change in production, productivity and measure other key indicators in relation to the objective of the study. A sample of 401 households were interviewed and data were collected through a questionnaire designed for the purpose of the study.

Focus group discussions

Focus groups were formed to discuss rehabilitation outcomes from the community perspective (met and unmet needs, challenges and recommendations), and to capture the performance of agriculture and the irrigation network after rehabilitation (including the change in cultivated areas, cultivated crops, yields etc.).

Key informant interviews

Qualitative in-depth interviews were conducted with local communities' representatives and experts where they provided their insight on the impact of the implemented activities, and challenges and opportunities at the community level. The performance of the WUAs as well as the performance of the irrigation system were also captured. Key informants included:

- WUAs representatives: the study of WUAs was presented based on observation through field visits to the study area and discussions with WUAs representatives, local community representatives, extensionists and experts in agriculture and water resources; and
- agriculture and irrigation experts as well as experts from the Ministry of Agriculture and Agrarian Reform and the Ministry of Water Resources.

Remote sensing derived data

Remote sensing allowed for the collection of information over large spatial areas and characterizing natural features (phenomena) or physical objects on the ground. Accurate assessment and periodic monitoring of natural resources using remote sensing techniques aids decision-makers to keep an eye on the optimal use of resources and make appropriate interventions. Remote sensing was useful in assessing the impact of interventions in relation to the following:

- agriculture: satellite images are usually used as mapping tools to classify crop types, examine their health and viability, estimate their yield, and map the soil characteristics and management practices;

- land cover/land use: producing land cover/land use maps from satellite imageries and monitoring its changes over time;
- environment: detecting and monitoring pollution sites, desertification, deforestation, extreme events, soil and vegetation degradation, soil erosion, and damage to infrastructure (e.g. roads, pipelines, irrigation networks, dams, etc.); and
- hydrology: remote sensing offers a synoptic view of the spatial distribution and dynamics of hydrological processes, often unattainable (or hard to be measured) by traditional ground surveys, e.g. evapotranspiration, evaporation, transpiration, etc.

Ground data on natural resources

Ground data on natural resources (groundwater level, water and soil quality) were collected from the field via the water resources information centre in Homs, which has been separately rehabilitated by FAO and provided with several measurement and quality monitoring devices for surface water and groundwater.

Data on the cost of the interventions

Data on the cost of the interventions included incurred costs at the activity level, such as technical support of fully dedicated human resources, in addition to estimates of other indirect costs, such as logistics, coordination, administration and transport.

Household sample size and sampling method

Sampling method

The stratified random sampling technique was used to identify the study sample. This means that the population subject of the study was divided into smaller groups (strata) based on a specific criterion and the sample units were then selected randomly and proportionally from each group (stratum). In this study the landholding size was used to divide the population subject of the study into three strata, see Table 2.

Table 2. Stratified sample criteria

Strata	Landholding size (donum*)	Percentage of households (%)
Stratum 1	Less than 5	21.92
Stratum 2	5 to 15	60.64
Stratum 3	More than 15	17.44

Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

*1 donum = 0.1 ha

The data on landholding size were taken from the extension units in the study area and the households were selected proportionally from each stratum; that was to ensure that each of the mentioned groups was well represented in the sample.

Sample size

The following formula by Yamane was used to calculate the sample size:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

- n is the sample size
- e is the precision level (5 percent)
- N is the population size

Accordingly, the sample size for a population of 20 000 with a confidence level of 95 percent and a precision level of 5 percent, the sample size is 392. A margin of 2 percent was added to compensate for possible invalid cases to formulate a total sample of 401 households.

Data on farmers' distribution and holding size were collected and filtered according to the criteria set for sampling using Microsoft Excel. The sample was then randomly and proportionately selected.

Data analysis

The capitalization study is a continuous process of collecting and analysing data to verify whether the intervention's objective is attained, particularly for the long term.

In this study, core indicators were proposed to reflect the short-term impacts and, to some extent, the mid-term impacts. When possible, these indicators were calculated, analysed and presented to give an overview of the socioeconomic and environmental impacts of the Al-Rastan irrigation intervention.

Data analyses methods included remote sensing technique for remote sensing derived data using Google Earth Engine and the FAO portal to monitor water productivity (WaPOR). The data from the household sample questionnaire were analysed using the Statistical Package for Social Sciences (SPSS). Surface and groundwater samples were analysed through water quality laboratory equipment.

Intervention background, activities and achievements

Qattina dam dates to the Roman era and was rebuilt in 1938 along with the irrigation network with a capacity of 200 million m^3. The dam lake is the main source for irrigating about 20 000 ha of agricultural land along the river course through Homs-Hama irrigation network that branches from the dam. Within Al-Rastan area, the irrigation network is designed to supply irrigation water for about 11 000 ha of agricultural land.

Al-Rastan is known for its fertile soil. Most of its inhabitants rely on agriculture as the main source of livelihood where they grow grains, vegetables and fruit trees such as citrus and almond. The irrigation network was seriously damaged during the crisis – causing a disruption to irrigated agriculture for more than nine years. The rehabilitation of Al-Rastan irrigation network was crucial for encouraging farmers to return to their land and restore agricultural production in the area after years of displacement.

Irrigation network and its main components

The main components of the irrigation network include:

Source of water

Qattina dam has a storage capacity of 200 million m^3. About 100 million m^3 is pumped for irrigation networks in Homs (72 million m^3) and Hama (25 million m^3). The main pumping station (22 pumping sets: 5.5 m^3/s; H: 10 m) at Qattina reservoir was rehabilitated by FAO under the project funded by the European Union in 2018.[1]

Irrigation network

The primary irrigation canal is 68 km in length. It passes through Homs and Hama governorates to irrigate about 20 695 ha, two-thirds of which are in Homs. The irrigation network was designed for an 11 m^3/s discharge rate (7.5 m^3/s for Homs and 3.5 m^3/s for Hama pumped and by gravity flow from the dam's lake) to provide all the network with water for irrigation according to a well-designed irrigation schedule. The irrigation system is a traditional, open channel network, an open trapezoidal section lined with concrete layers. The network consists of:

- the primary concrete lined irrigation canal, is 68 km in length;

[1] FAO project funded by the European Union: Strengthening the resilience of crisis-affected people and their host communities for food and nutrition security in the Syrian Arab Republic (OSRO/SYR/601/EC).

- thirteen concrete lined irrigation branches (secondary, field network) of 116 km in length;
- tertiary earthen irrigation canals 600 km in length;
- earthen drainage network of 250 km length; and
- fifteen irrigation management centres and several siphons, gates, water bridges, regulators, service roads etc.

In addition, there are a number of ancient Roman irrigation canals that branch directly from Orontes River, ten in Homs and eight in Hama. Their length varies from 4 to 20 km and the discharge rate is between 0.5 and 1.5 m^3/s.

Targeted area: 11 000 ha.

Beneficiaries: 20 000 households.

Targeted villages: 20 villages (Al-Khaldieh, Tair Maaleh, Al-Dar Al-Kabiereh, Jabbourine, Al-Ghanto, Al-Dwair, Dair Baalbeh, Om Sharshouh, Al-Thawrah, Al-Rastan, Talbiseh, Farhaneih, Gharb and Shark, Zaafaraneh, Al-Mokhtarieh, Al-Najmeh, Al-Ashrafieh, Ghornatah, Al-Almkaramieh and Al-Hashmieh).

Intervention activities

The intervention was composed of three main activities:

Activity 1. rehabilitation of the local irrigation network and related infrastructure to open access to water for small holder farmers;

Activity 2. maintenance works for the concrete lined on-farm irrigation network and related groundwork, including field branch canal number 1, 2 and 3 (branch 2 consists of 2A and 2B branches), and five irrigation management centres for the WUAs in Al-Rastan; and

Activity 3. rehabilitation of the field branch canals 1, 2, and 3 (60 km length), tertiary canals (20 km) and Ghneih Al-Assi Roman irrigation canal (8 km) to open access to water for field irrigation.

Rehabilitation works during implementation

© FAO technical team

© FAO technical team

To ensure sustainability of water resources and promote fair distribution of irrigation water among farmers, six WUAs were established. Management board members of the established WUAs were trained on the roles of the WUAs and the responsibilities of WUAs management board, the principles and practices of water resources management, and operation and maintenance of irrigation networks.

A capacity building programme that included 40 trainees selected from targeted areas to train 800 farmers was implemented to enhance irrigation management knowledge and related practical skills. The main topics of the training activity included basic information about irrigation and drainage systems, efficient irrigation techniques, crop water requirements, irrigation scheduling, and operation and maintenance. The WUA concept, to ensure good water governance, fair and sustainable use of water in agriculture, was also introduced.

The participatory approach was implemented to reach the goal of improved farmers' water management by involving and encouraging farmers to have an active role in the learning process. This is believed to lead to better performance at the local level.

All activities were conducted with a 100 percent implementation rate as presented in Table 3 and with a larger number of beneficiaries considering returnees who benefited from the rehabilitation directly by restoring their main source of livelihood and indirectly by benefiting from the emerging agriculture-related activities in the target area.

Table 3. Intervention's achievements and completion rate

Main activity	Activity	Achieved	Completion rate (%)
Rehabilitation of the Al-Rastan irrigation network	Rehabilitation of the local irrigation network and related infrastructure	local irrigation network and related infrastructure rehabilitated	100
	Maintenance works for the concrete lined on-farm irrigation network	farm irrigation network maintained, and five irrigation management centres rehabilitated	100
	Rehabilitation field branch canals (1, 2, and 3), tertiary canals, and Ghneih Al-Assi Roman irrigation canal	field branch canals, tertiary canals, and Ghneih Al-Assi Roman irrigation canal rehabilitated	100
Capacity building programme	Training of trainers	40 technical staff members trained	100
	Farmers' training	800 farmers trained in irrigation management knowledge and practical skills	100
Establishment of WUAs	Establishment of six WUAs for irrigation management at field level	six WUAs established and members were given initial training on the roles of the WUAs and responsibilities of the WUA management board	100
Capitalization workshop	Capitalization workshop (for dissemination of findings, recommendations and the way forward)	40 stakeholders including experts, farmers and technical staff gathered to discuss findings, recommendations and the way forward	100

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study.

Main indicators

The results of data analyses are divided into seven sections and detailed below based on the main pillars of the study and type of analysis employed.

1. The impact of the rehabilitation on agricultural production and productivity in the study area includes the following indicators:
   - changes in cultivated areas with summer crops;
   - changes in production of summer crops;
   - changes in cultivated areas with winter crops;
   - changes in production of winter crops;
   - changes in cultivated areas with other crops; and
   - changes in production of other crops.

2. Demographic indicators include:
   - gender, age and education of the household head;
   - household size; and
   - landholding size.

3. The results of the socioeconomic study present a description of the socioeconomic status of the study sample and the associations between different variables through the following indicators:
   - participation in WUAs (in relation to gender and access to irrigation water);
   - participation in the capacity building programme and its relevance;
   - landholding size relation to gender;
   - changes in rainfed and irrigated areas;
   - agricultural production/cultivated crops with cultivated areas and change in productivity;
   - benefit–cost ratio of cultivated crops;
   - livestock activities and change in livestock numbers;
   - income per productive unit and its relation to access to irrigation water;
   - food security and its relation to gender, holding size, livestock activities and access to irrigation water;
   - land value and the change in land value after rehabilitation; and
   - number of returnees.

   The socioeconomic study further discussed the marketing channels in the study area with main challenges and employment opportunities generated as a result of rehabilitation and resuming agricultural activities in the study area.

4. Intervention cost analysis which aimed at assessing the costs of investments and additional income to the community in the study area as a result of rehabilitation to arrive at the return on investment. The study includes:
    - estimated benefits based on the income generated by the increased cultivated areas with different crops after rehabilitation;
    - intervention costs estimated at activity level; and
    - profitability of the intervention through return on investment.

5. The study of WUAs includes:
    - roles of the WUAs and responsibilities of WUAs management boards;
    - relevance of WUAs to water governance;
    - role of WUAs in management and sustainability; and
    - participation of women in WUAs.

6. Study of the intervention's impact on surface and groundwater includes:
    - groundwater: studying groundwater levels in observation wells, laboratory analyses of groundwater samples, and main findings on groundwater quality and its suitability for irrigation and domestic use; and
    - surface water: laboratory analyses of surface water samples and findings on water quality and its suitability for irrigation.

7. Results of the remote sensing study on the intervention's impact on agriculture, environment, and natural resources. For a multidimensional comprehensive study, remote sensing data has been acquired and analysed to produce several indicators including:
    - change in area cultivated with summer crops;
    - change in area cultivated with winter crops;
    - Normalized Difference Vegetation Index (NDVI);
    - change in net primary production;
    - total biomass production;
    - leaf area index;
    - Albedo (reflected sunlight);
    - land surface temperature; and
    - Normalized Difference Moisture Index (NDMI).

Findings and results

The impact of the rehabilitation on agriculture in the study area

It was reported by the local stakeholders that the agricultural production has significantly increased after opening access to water for irrigation through the rehabilitation of the Al-Rastan irrigation network and related infrastructures. Farmers were able to cultivate their lands with summer and winter crops. In addition, they were able to bridge the gap between the two seasons and cultivate other crops such as soybean, sunflower, maize, dry bean, and potato among others. Prior to the rehabilitation works, only limited areas were cultivated with these crops using only groundwater since pumping is relatively expensive.

Cultivating these crops increased generated income from agricultural land, more crop diversity, and food availability for local communities all year long.

Table 4 shows the cropping pattern (sequence of crops in one year) in Al-Rastan area with their periods and the main summer, winter, and other crops.

Table 4. Cropping pattern in Al-Rastan district, normally practiced sequence of crops in one year

Cropping season	Summer season: summer crops	In between seasons: other crops	Winter season: winter crops
Planting to harvesting (average)	April to September/ November, depends on the crop's growing period	June to October/November, depends on the crop's growing period	September/December to June
Main crops	Early varieties of sunflower and maize, sesame, and vegetables such as Cucumber, tomato, melon, pepper, eggplant, and zucchini Cotton and sugar beets used to be cultivated and were stopped years before the crisis	Soybean, sunflower, maize, dry bean, potato	Wheat, barley, anise, black seed, garlic, onion, legumes, potato (winter variety), etc.

Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

Official statistics of the study area were obtained from the Directorate of Agriculture in Homs to capture the impact of irrigation on cultivated areas, production, and productivity of crops in all seasons: summer crops, winter crops, and other crops. It is concluded that the area and production have significantly increased as shown in Table 5 and demonstrated in the following paragraphs.

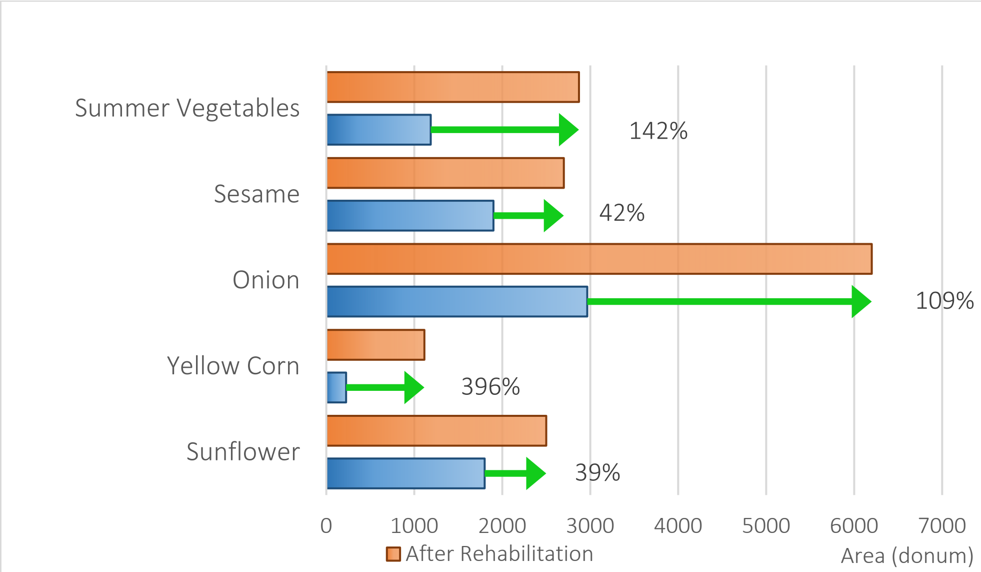
Table 5. Increase in cultivated areas and production for all crops in all cropping seasons in Al-Rastan district

	Crop	Cultivated area before rehabilitation (ha)	Cultivated area after rehabilitation (ha)	Increase in cultivated area after rehabilitation (ha)	Increase in cultivated area after rehabilitation (%)	Production before rehabilitation (tonne)	Production after rehabilitation (tonne)	Increase in production after rehabilitation (tonne)	Increase in production after rehabilitation (%)
Summer crops	Sunflower	180	250	70	39	450	1 000	550	122
	Maize	23	112	89	396	192	1 643	1 451	756
	Onion	297	620	323	109	4 392	12 230	7838	178
	Sesame	190	270	80	42	285	540	255	89
	Vegetables	119	287	169	142	1 708	5 242	3 534	207
	Total	**808**	**1 539**	**731**	**90**				
Winter crops	Wheat	4 479	5 064	585	13	15 826	26 430	10 604	67
	Black seed	300	500	200	67	435	650	215	49
	Anise	750	1 090	340	45	810	1 515	704	87
	Coriander	68	138	70	103	60	111	51	85
	Garlic	324	605	281	87	1 688	4 975	3 287	195
	Onion	12	144	132	1 099	250	2 678	2 428	971
	Potato	257	549	292	114	2 947	7 889	4 942	168
	Vegetables	216	380	165	76	2 558	4 291	1 733	68
	Total	**6 406**	**8 470**	**2 064**	**32**				
Other crops	Soybean	200	361	162	81	372	786	413	111
	Maize	26	211	185	710	52	737	685	1 317
	Dry bean	56	239	183	328	346	650	304	88
	Potato	185	368	183	99	2 904	5 456	2 552	88
	Sunflower	30	294	264	895	49	1 267	1 218	2 498
	Vegetables	51	282	231	453	544	5 162	4 619	850
	Total	**547**	**1 754**	**1 207**	**221**				

Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

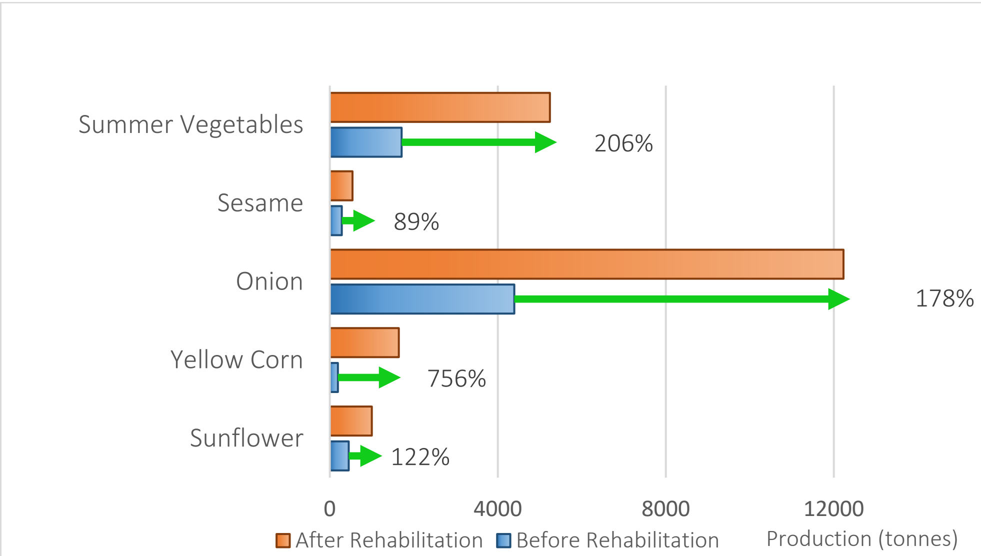
Summer crops have benefited from irrigation after rehabilitation and were cultivated in larger areas with more productivity compared to previous seasons before the rehabilitation. It was estimated that cultivated area under summer crops increased from 808 ha to 1 539 ha equivalent to a 90 percent increase. The increase in production as a result of the increase in yield and cultivated area was most noticeable in yellow corn and summer vegetables (mainly cucumber, eggplant, pepper and watermelon) with an estimated increase of 756 percent and 206 percent respectively, see Figure 2. Production of other summer crops such as early varieties of sunflower, maize, onion, sesame, and vegetables which are famous to in the area has also increased considerably. For instance, the production of onion and sunflower increased by 178 percent and 122 percent respectively, see Figure 3.

Figure 2. Change in areas cultivated with summer crops in the study area



Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

Figure 3. Change in the production of summer crops in the study area



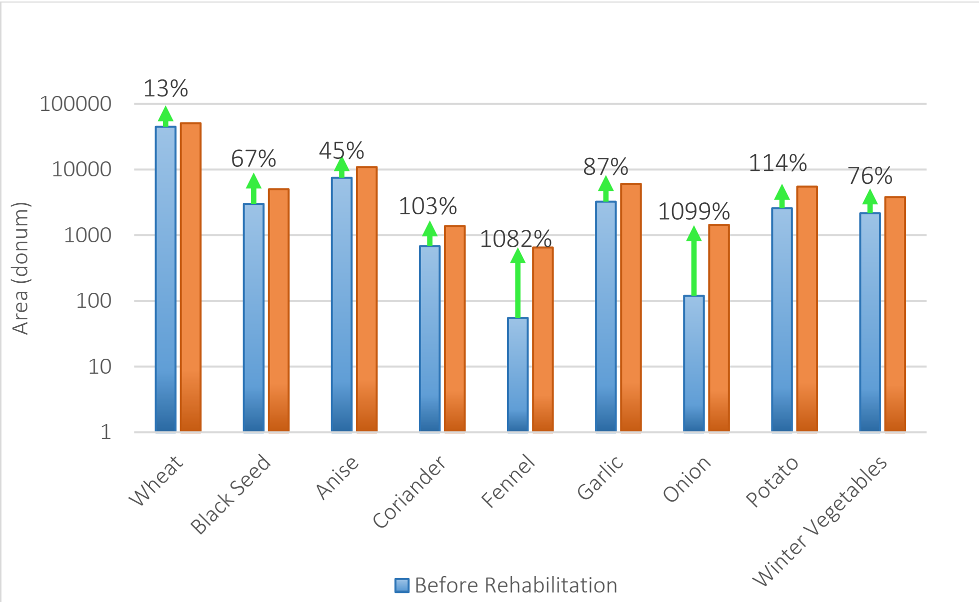
Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

Similar results were obtained for winter crops with an additional 2 064 ha under cultivation compared to the previous year before having access to irrigation (cultivated area increased from 6 406 ha to 8 470 ha, equivalent to 32 percent). It was reported through discussions with the local community that the winter crops (rainfed) used to be susceptible to the variability of rainfall as one of the adverse effects of climate change.

In the 2021 season, winter crops received supplemental irrigation from the rehabilitated irrigation network which improved the production of the strategic crop in the area. As a result, production of wheat increased by 67 percent in 2021 compared to the previous season while it increased by 971 percent, 195 percent and 168 percent for onion, garlic and potato respectively. Figure 4 and Figure 5 show the increase in cultivated areas and production of winter crops.

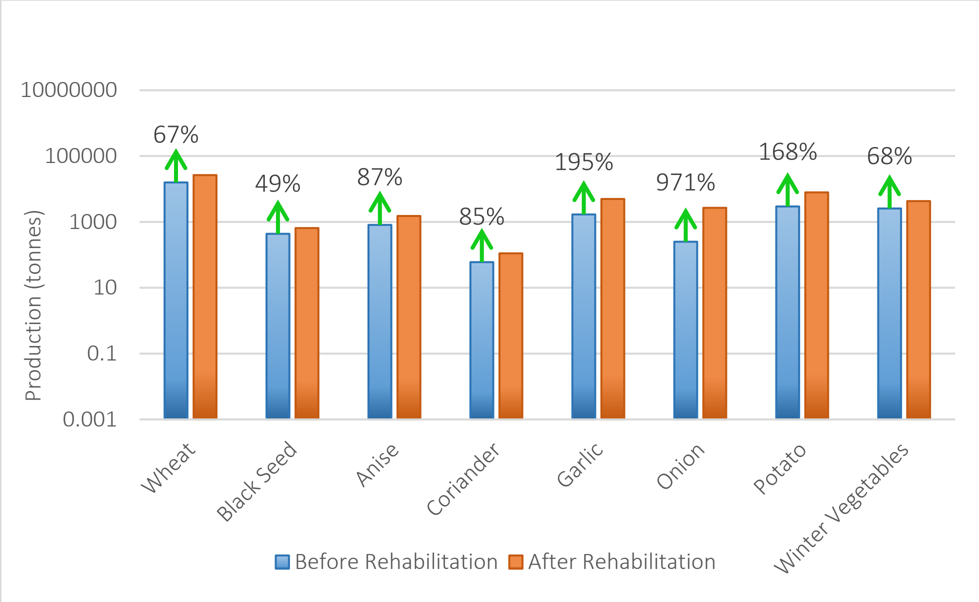
The area cultivated with other crops (crops in between summer and winter seasons) has increased by 1 208 ha (from 547 to 1 754 equivalent to 221 percent) in the study area due to access to irrigation water. The cultivation of these crops was only limited before rehabilitation since they are dependent on irrigation. Figure 6 and Figure 7 show the increase in cultivated area with other crops.

Figure 4. Change in areas cultivated with winter crops in the study area



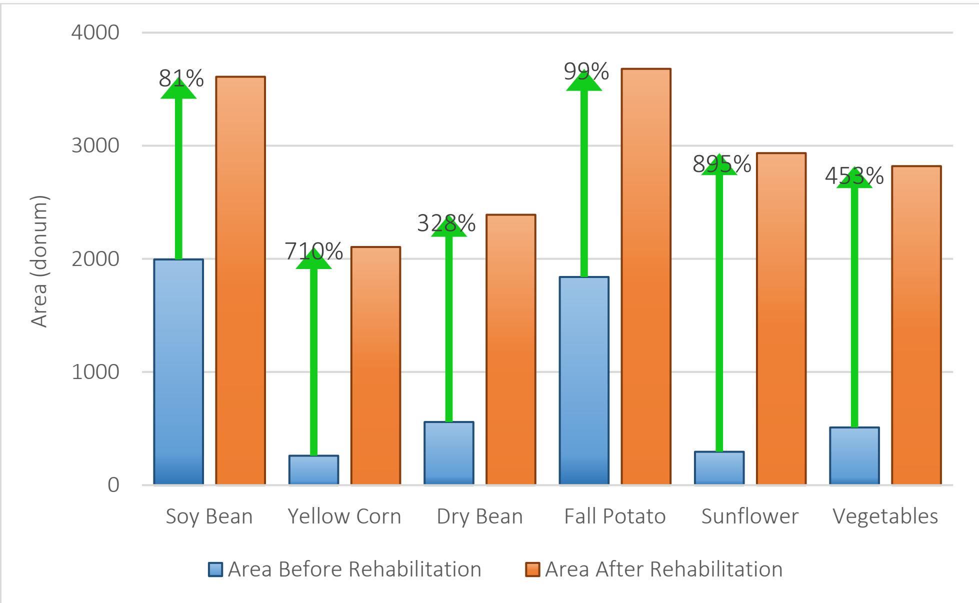
Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

Figure 5. Change in the production of winter crops in the study area



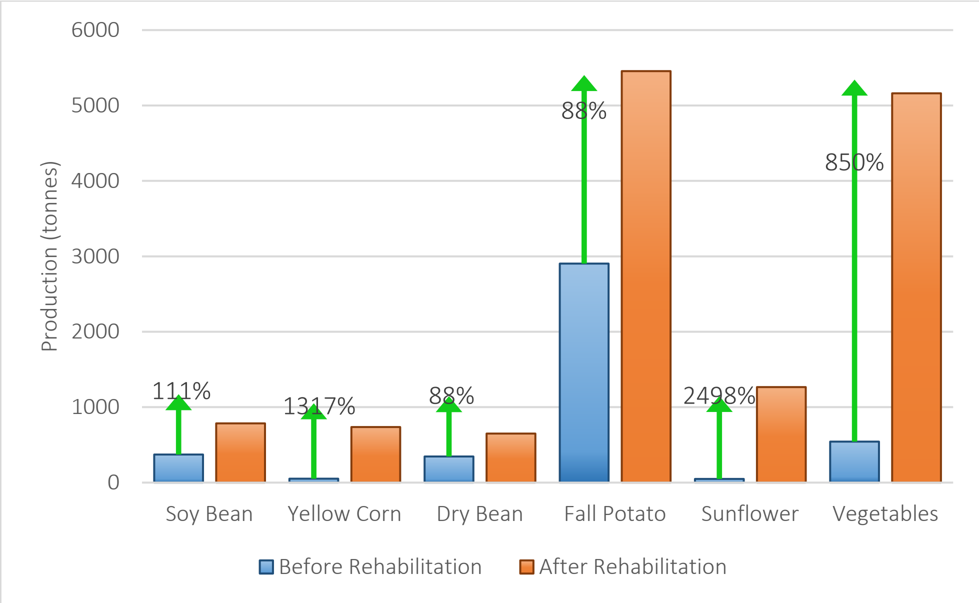
Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

Figure 6. Change in areas cultivated with other crops in the study area



Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

Figure 7. Change in the production of other crops in the study area



Source: Syrian Ministry of Agriculture and Agrarian Reform. 2022. Agriculture database. In: *MOAAR*. Damascus. [Cited 15 January 2023]. http://moaar.gov.sy

Demographic characteristics of the study sample

The socioeconomic characteristics of the study sample were captured to develop a general understanding of the community subject of the study with a focus on aspects of interest in relation to the rehabilitation intervention and its impacts.

Gender of the household head

The analysed results of the study sample show that among the study sample of 401 households, 58 households equivalent to 14.5 percent were women headed while 343 households equivalent to 85.5 percent were men headed, see Table 6.

Table 6. Gender of the household head in the study sample

Household head	Frequency	Percent	Valid percent	Cumulative percent
Man	343	85.5	85.5	85.5
Woman	58	14.5	14.5	100.0
Total	401	100.0	100.0	

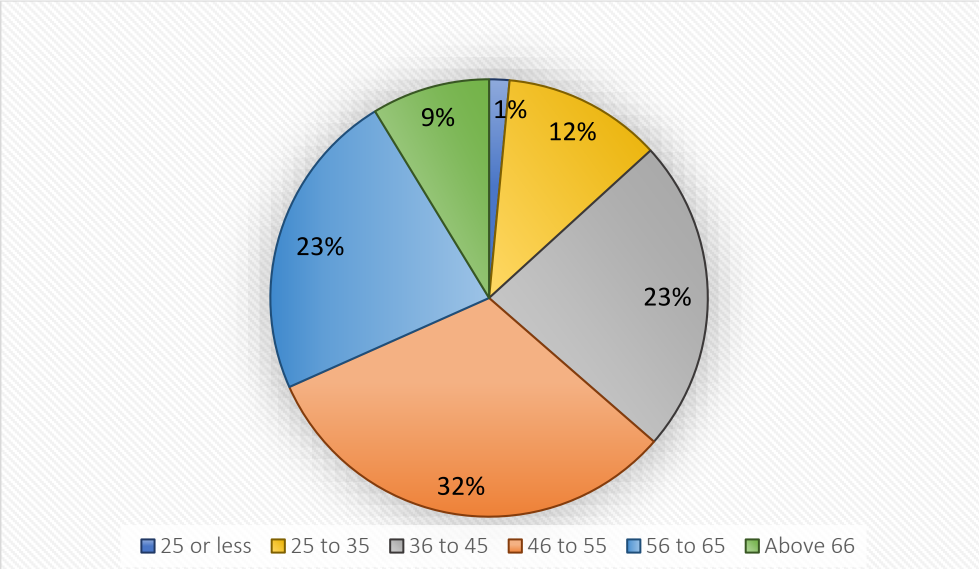
Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Age of the household head

The age of respondents ranged from 21 to 80 years of age with a mean of 50. Age was divided into six groups. The results show that the majority of the respondents 80.5 percent were aged 36 to 65 years of age and fell into the three age groups of

36 to 45, 46 to 55 and 56 to 65 with percentages of 23.2 percent, 31.9 percent, and 22.9 percent respectively, see Figure 8.

Figure 8. Distribution of households according to age groups in the study sample



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Education

According to the study sample, 72.6 percent of the farmers had basic education through elementary school, 14 percent went to secondary school, while those who had a higher education through intermediate institutions and universities constituted 5 and 8.5 percent of the study sample respectively, see Table 7.

Table 7. Level of education of the household head

Education	Frequency	Percent	Valid percent	Cumulative percent
Elementary school	291	72.5	72.5	72.5
Secondary school	56	14	14	86.5
Intermediate institution	22	5	5	91.5
University	34	8.5	8.5	100.0
Total	401	100.0	100.0	

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Household size

The household size ranged from 1 to 13 members with a mean of 6 and a standard deviation of 2.1. The size of household was divided into four groups: three members or less; four to six members; six to nine members; and ten members or above. The results show that most of the respondents (86.5 percent) had a household size of four to nine members, see Table 8 and Table 9.

Table 8. Household size statistics

	N	Range	Minimum	Maximum	Mean	Std. deviation	Variance
Household size	401	12	1	13	6	2.1	4.5

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Table 9. Distribution of the study sample according to household size groups

Household size groups	Frequency	Percent	Valid percent	Cumulative percent
3 members or less	28	7.0	7.0	8.0
4 to 6 members	252	62.8	62.8	66.8
7 to 9 members	95	23.7	23.7	92.0
10 members or above	26	6.5	6.5	100.0
Total	401	100.0	100.0	

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Landholding size

The sample was divided into three groups according to the landholding size: less than 5 donums, 5 to 15 donums and above 15 donums which corresponds to the distribution of households in the target area. This allowed for demonstrating attributes of the different groups and their relation to other tested variables in the study, see Table 10.

Table 10. Distribution of the study sample on landholding groups

Landholding groups	Frequency	Percent	Valid percent	Cumulative percent
Less than 5 donums	89	22.2	22.2	22.2
5 to 15 donums	233	58.1	58.1	80.3
Above 15 donums	79	19.7	19.7	100.0
Total	401	100.0	100.0	

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Landholding groups by gender of the household head

Cross tabulation and chi-square test were undertaken to test the association between the gender of the household head and the landholding size groups. Results showed that men had larger landholding size than women (Table 11) with a significant coefficient of the chi-square test (Table 12) which supports the fact that it is less likely for women to have access to large farms compared to men which tends to make women more vulnerable.

Table 11. Landholding groups by the gender of the household head

Household head		Holding size groups			Total
		4 donums or less	5 to 15 donums	above 15 donums	
Man	No. of households	68	197	78	343
	% of total	17%	49.1%	19.5%	85.5%
Woman	No. of households	21	36	1	58
	% of total	5.2%	9.0%	0.2%	14.5%
Total	No. of households	89	233	79	401
	% of total	22.2%	58.1%	19.7%	100 %

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Table 12. Chi-square test of association between landholding group and gender of the household head

	Value	df	Asymptotic significance (2-sided) *
Pearson chi-square	17.305	2	.000
Likelihood ratio	22.894	2	.000
Linear-by-linear association	21.205	1	.000
No. of valid cases	401		

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

*Significance value below 0.05 indicates a significant association.

Socioeconomic characteristics

Participation in WUAs

Among the interviewed households, 86 farmers (21.45 percent) reported their participation in one of the six WUAs established within the framework of the intervention. Of those, 14 women-headed households (3.49 percent of the total household sample) reported that the woman or other member of the household is associated with one of the established WUAs, see Table 13.

Table 13. Participation in WUAs by the gender of the household head

		Participation in WUAs		Total
		Yes	No	
Household head	Man	17.96%	67.58%	85.54%
	Woman	3.49%	10.97%	14.46%
Total		21.45%	78.55%	100%

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Although not all respondents were directly involved in the WUAs activities, the majority (91 percent) reported getting their fair share of irrigation water during the irrigation season of 2021, see Table 14.

Table 14. Receiving required water by farmers in WUAS (2021 irrigation season)

		Farmers who received the required irrigation water		Total
		Yes	No	
Members of WUAs	Yes	81	5	86
	No	284	31	315
Total		365	36	401

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

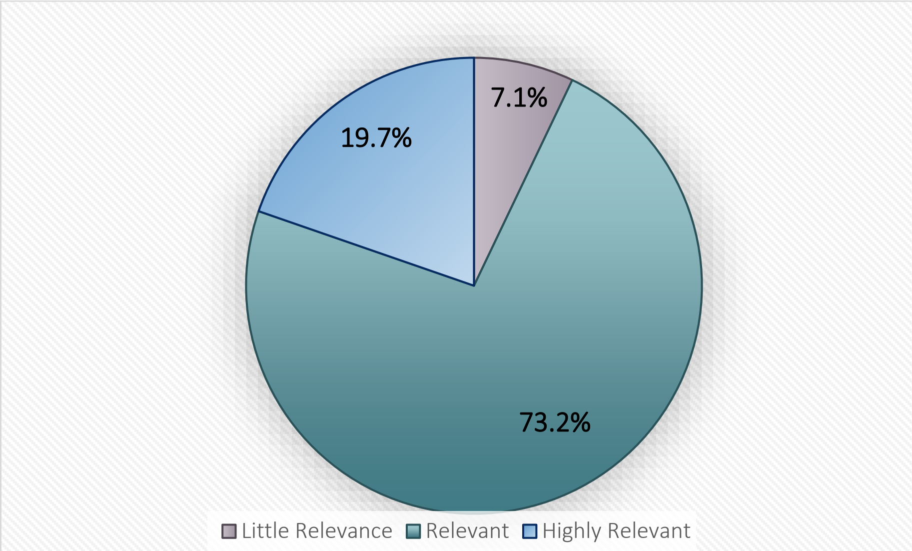
The main challenges of receiving the required irrigation water were discussed with the local community and the key informants through several meetings. These challenges included:

- Some parts of the irrigation network still need some extra work in terms of reshaping and cleaning which hindered the access to irrigation water. As the transfer of irrigation management to the farmers was in its first steps, farmers needed more time to properly take their role in operation and maintenance, this is why farmers were unable to cover all required work before the irrigation season had started.
- In locations run by WUAs, the set participatory irrigation management approach strongly depends on willingness, trust and sense of ownership by farmers to perform their roles. This process is well recognized by farmers, and they are getting more involved in it but still needs a lot of efforts to be enhanced so that it is properly implemented. In the areas where WUAs are yet to be established, some violations and conflicts over the irrigation water were reported.
- Irrigation schedules were prepared according to crop water requirements, irrigated area and water availability. It was reported that in 2021, water authorities released irrigation loads according to the irrigation programme and WUAs followed the irrigation schedules as planned. However, some farmers prefer to apply more water than is needed and for those, the received water didn’t meet their expectations.

Participation in the capacity building programme and its relevance

The results of the analysis showed that 31.7 percent of the study sample were involved in at least one of the training activities, whether the capacity building programme for farmers or the training of the WUAs board members upon establishment. In terms of the relevance of the capacity building programme in enhancing knowledge and skills, 73.2 percent of farmers found it to be relevant, 19.7 percent highly relevant while 7.1 percent thought it had little relevance, see Figure 9.

Figure 9. Relevance of the capacity building programme



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Change in cultivated, rainfed and irrigated area at the sample level

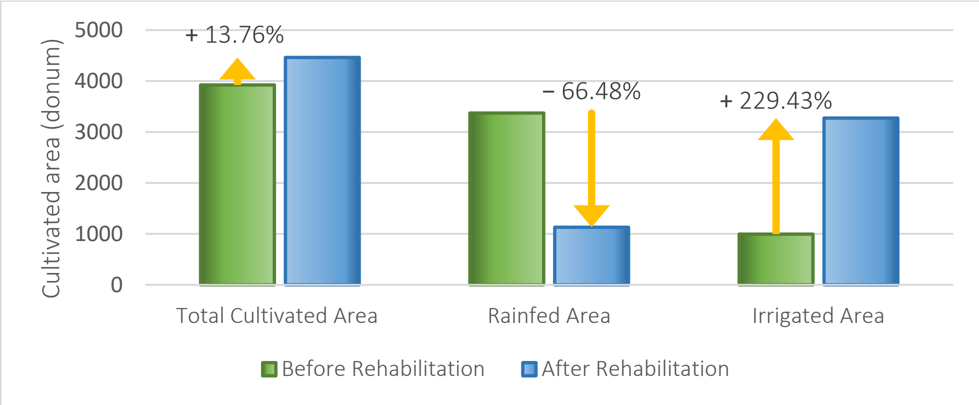
According to the study sample, the irrigated area has increased significantly after the rehabilitation of the irrigation network. This allowed farmers to cultivate more diversified crops with more productivity and to benefit from more intensive cropping which depends totally on irrigation. The farmers reported that the total cultivated area has increased by 13.76 percent equivalent to 540 donums. Switching from rainfed to irrigated cultivation after rehabilitation caused the rainfed area to decrease by 66.48 percent equivalent to 2 242 donums while the irrigated area increased by 229.43 percent equivalent to 2 284 donums compared to 995.5 donums before rehabilitation, see Table 15 and Figure 10.

Table 15. Change in the rainfed and irrigated area at the sample level

Descriptive statistics	Total cultivated area (donum)		Rainfed area (donum)		Irrigated area (donum)	
	Before rehabilitation	After rehabilitation	Before rehabilitation	After rehabilitation	Before rehabilitation	After rehabilitation
Mean	9.78	11.13	8.41	2.82	2.48	8.18
Std. deviation	8.13	9.62	7.94	6.53	6.66	7.31
Variance	66.05	92.60	62.98	42.65	44.30	53.49
Sum	3 923.00	4 463.00	3 372.50	1 130.50	995.50	3 279.50
Change	↑13.76%		↓66.48%		↑229.43%	

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Figure 10. Change in cultivated, rainfed and irrigated area at the sample level



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Agricultural production

For the interviewed farmers, agricultural production included many activities: crop cultivation, animal husbandry, poultry raising (mainly domestic chickens) and beekeeping.

Farmers reported that they have been able to cultivate more crops during the past season due to availability of the irrigation water. This was translated into increased and diversified production. Farmers were able to cultivate summer, winter and other crops along the year 2021. The main cultivated crops in all cropping seasons at the sample level are presented in Table 16.

Table 16. Types of cultivated crops at the sample level

No.	Crop type	No. of households	Total cultivated area (donum)	Average cultivated area by farmer (donum)	Percentage of total cultivated area (%)
1	Wheat	297	3429.5	11.55	76.84
2	Anise	98	546.0	5.57	12.23
3	Vegetables	158	404.7	2.56	9.07
4	Soybean	62	262.5	4.23	5.88
5	Black seed	59	255.6	4.33	5.73
6	Potato	40	231.0	5.78	5.18
7	Coriander	51	225.0	4.41	5.04
8	Barley	18	162.0	9.00	3.63
9	Cumin	19	118.0	6.21	2.64
10	Sunflower	32	107.5	3.36	2.41
11	Yellow corn	23	89.0	3.87	1.99
12	Sesame	15	41.0	2.73	0.92
13	Onion	8	24.0	8.00	0.54
14	Garlic	5	22.5	4.50	0.50

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Data on agricultural production before and after rehabilitation were obtained from the study sample and at the study area level from official statistics. Results at both levels showed increased areas and productivity. The increase in productivity and the cultivated area was most noticeable in other crops (in between summer and winter seasons) as they highly depend on irrigation. Before rehabilitation, cultivation of these crops was limited to a small percentage of farmers who used private groundwater wells, which was associated with high pumping costs, over exploitation of groundwater and conflicts among farmers.

Farmers reported a significant increase in the productivity of summer vegetables from an average of 357 kg/donum to an average of 1 090 kg/donum. The productivity of yellow corn, soybean and potato increased from 350, 100 and 1 825 kg per donum to 600, 200 and 2 965 kg per donum respectively. Farmers also reported that the productivity of winter crops has increased benefiting from supplementary irrigation. For wheat, it increased from an average of 181 kg/donum to an average of 349 kg/donum. Similarly, the productivity of spices such as anise, coriander and black seed has increased considerably from an average of 78, 80 and 70 kg/donum to an average of 120, 134 and 125 kg/donum respectively. Table 17 shows the change in productivity of cultivated crops as reported by interviewed farmers.

Table 17. Change in the productivity of cultivated crops at the sample level

			Productivity before rehabilitation			Productivity after rehabilitation		
No.	Crop	N	Mean	Std. deviation	Variance	Mean	Std. deviation	Variance
1	Wheat	297	180.83	33.89	1 148.23	349.17	50.56	2 556.74
2	Anise	98	77.70	21.77	473.81	120.16	23.64	558.77
3	Vegetables	158	357.32	114.32	13 070.12	1 090.30	414.17	171 533.24
4	Soybean	62	100.00	17.56	308.33	200.32	51.18	2 619.57
5	Black seed	59	69.92	20.90	436.63	125.22	40.13	1 610.45
6	Potato	40	1 825.00	633.97	401 923.08	2 965.00	727.15	528 743.59
7	Coriander	51	79.71	11.89	141.41	133.92	30.76	946.31
8	Barley	18	130.00	26.08	680.00	169.23	55.60	3 091.03
9	Cumin	19	43.95	14.20	201.61	93.16	13.36	178.36
10	Sunflower	32	135.00	31.27	977.78	231.09	86.15	7 422.15
11	Yellow corn	23	350.00	37.80	1 428.57	600.00	106.60	11 363.64
12	Sesame	15	95.00	5.00	25.00	106.67	14.96	223.81
13	Onion	8	940.00	157.76	24 888.89	1 790.00	354.18	125 444.44
14	Garlic	5	475.00	77.06	5 937.50	822.00	98.34	9 670.00

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Benefit–cost ratio for cultivated crops

The benefit–cost ratio (BCR) is a profitability indicator that shows the relationship between the relative costs and benefits expressed in monetary terms. If BCR is greater than 1, the benefits outweigh the costs and if BCR is less than 1, the costs outweigh the benefits. BCR was calculated for major crops cultivated at the sample level based on collected data on farmers' production, sales and total costs.

- BCR for crop = total revenue/total variable costs.
- Total revenue = yield of crop * farm gate price.

The BCR for the cultivated crops at the sample level ranged from 1.05 and 1.85 for barley and wheat respectively to 3.54 and 3.08 for soybean and yellow corn respectively. This can be directly related to irrigation which allowed for the cultivation of other crops between winter and summer seasons. Table 18 shows the BCR based on farmers' production, sales, and total costs calculated as average for 1 donum of cultivated area.

Table 18. BCR for cultivated crops at the sample level

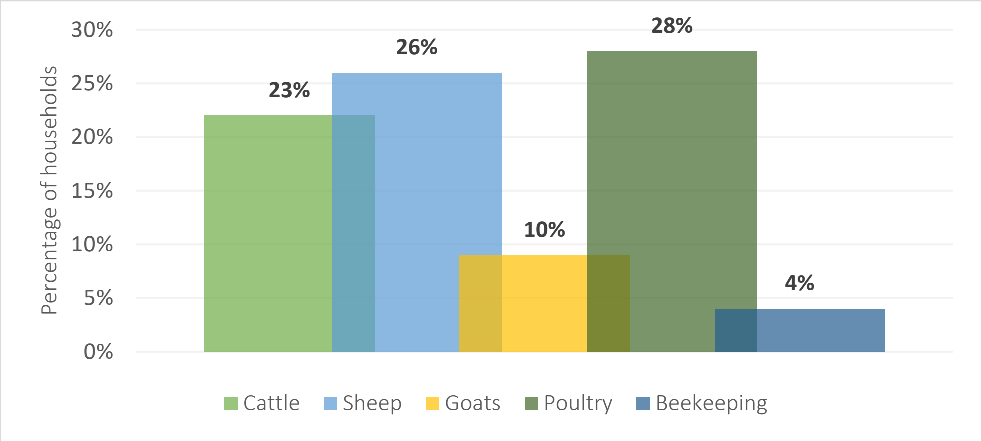
		Costs (SYP per 1 donum)							Benefits (SYP per 1 donum)			
No.	Crop	Seeds (SYP)	Fertilizers (SYP)	Pesticides (SYP)	Labour (SYP)	Machinery (SYP)	Marketing (SYP)	Total (SYP)	Productivity (kg/donum)	Unit price (SYP)	Revenue (SYP)	BCR
1	Wheat	19 313	23 831	21 811	35 476	49 428	8 290	158 149	349	840	292 954	1.85
2	Anise	25 407	33 564	45 769	54 721	48 696	11 505	219 662	120	4 882	586 664	2.67
3	Vegetables	39 969	38 781	25 623	82 159	70 000	75 183	331 715	1 090	843	919 329	2.77
4	Soybean	18 295	8 826	11 264	17 938	36 807	4 533	97 663	200	1 728	346 140	3.54
5	Black seed	16 000	12 490	17 778	58 056	54 519	5 703	164 544	125	4 798	600 763	3.65
6	Potato	129 286	71 429	40 391	64 281	189 667	83 896	578 949	2 965	335	992 601	1.71
7	Coriander	10 019	13 000	16 819	44 082	40 790	5 768	130 478	134	2 563	343 411	2.63
8	Barley	11 071	16 548	13 036	34 406	29 386	3 960	108 407	169	675	114 231	1.05
9	Cumin	22 769	24 000	28 000	41 346	49 904	5 300	171 319	93	5 146	477 009	2.78
10	Sunflower	25 856	23 297	26 984	166 188	110 734	15 916	368 975	231	3 066	708 447	1.92
11	Yellow corn	10 349	14 116	17 389	44 508	54 302	14 457	155 121	600	795	477 143	3.08
12	Sesame	36 000	23 659	27 333	53 331	46 000	8 847	195 170	107	4 340	465 827	2.39
13	Onion	54 815	34 815	45 158	128 500	153 571	62 775	479 635	1 790	405	724 950	1.51
14	Garlic	86 600	52 195	47 205	135 061	88 920	82 967	492 948	822	1 000	822 314	1.67

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, Excel output.

Livestock, poultry and beekeeping

Agricultural activities were not limited to crop production but also included livestock production (cattle, sheep and goats) in addition to raising poultry and beekeeping. Results showed that 28 percent of households raised poultry (mostly for domestic use), 26 percent raised sheep while 23 percent raised cattle, see Figure 11.

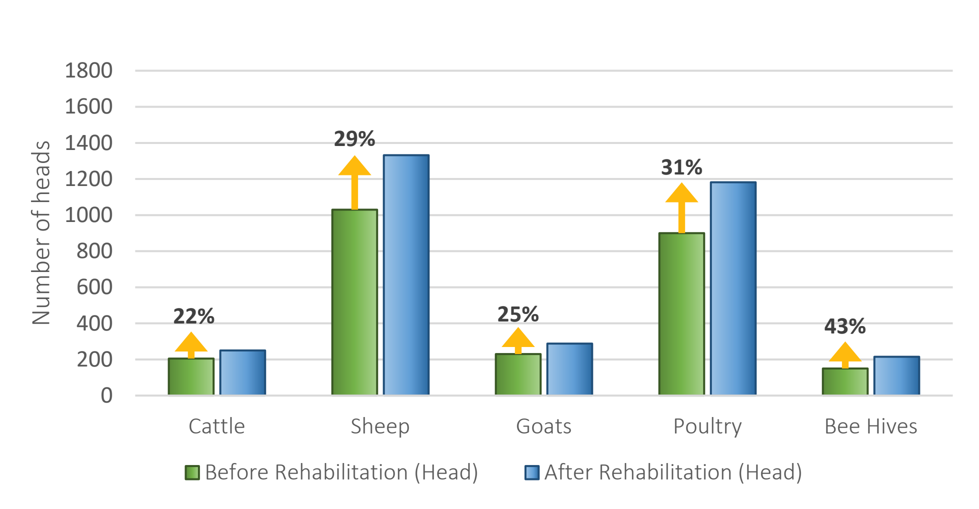
Figure 11. Proportions of livestock activities at the sample level



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Farmers reported that the availability of water after rehabilitation has contributed positively to livestock production as it provided a source of water and feed due to diversified agricultural production (benefiting from feed crops and crop residues as livestock feed). Despite the sharp rise in feed prices and husbandry costs, there was still an increase in livestock numbers. Figure 12 demonstrates the change in livestock numbers at the sample level between 2020 and 2021. Tables 19, 20 and 21 show the average holding of livestock at the sample level with average production, revenue and costs for 2021.

Figure 12. Change in the number of livestock at the sample level



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Table 19. Average holding of livestock with average revenue at the sample level in 2021

Type	Number of farmers with holding	Average holding per farmer	Type of production	Average production (litre, kg)	Quantities sold (kg)	Unit price (SYP)	Income per type of production (SYP)	Total income (SYP)
Cattle	93	2	Milk	3 430	2 960	1 350	3 995 585	5 801 004
			Meat	321	228	7 926	1 805 419	
Sheep	103	10	Milk	69	55	1 817	99 917	583 670
			Meat	47	38	12 059	463 151	
			Wool	3	3	7 500	20 603	
Goats	40	6	Milk	192	164	1 440	236 160	548 396
			Meat	60	43	7 186	312 236	

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Table 20. Average costs per head of livestock at the sample level in 2021

Type	Costs (SYP/Head)				Total	BCR
	Feed	Veterinary and health care inputs	Other purchases	Labour		
Cattle	4 307 000	129 333	63 333	638 462	5 138 129	1.13
Sheep	330 909	57 750	45 071	87 500	521 231	1.12
Goats	179 456	45 763	21 500	95 526	342 246	1.60

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Table 21. Average holding of poultry and beehives at the sample level with estimated costs and revenue in 2021

Type	No. of farmers with holding	Average holding per farmer	Production (per 1 head/hive)	Unit price (SYP)	Production cost (SYP)	Income (SYP)	BCR
Poultry	112	10.23	153 (egg)	391	31 652	59 888	1.89
Beehives	16	11.88	12.92 (kg honey)	18 168	183 333	234 731	1.28

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Income per productive unit (land)

The income for productive unit (land) was calculated based on farmers' responses on revenue and various costs. The gross margin analysis was conducted for farms' costs and returns. Gross margin is the difference between the total revenue and the total variable cost, and it is expressed as:

$$GM = TR - TVC$$

Where:

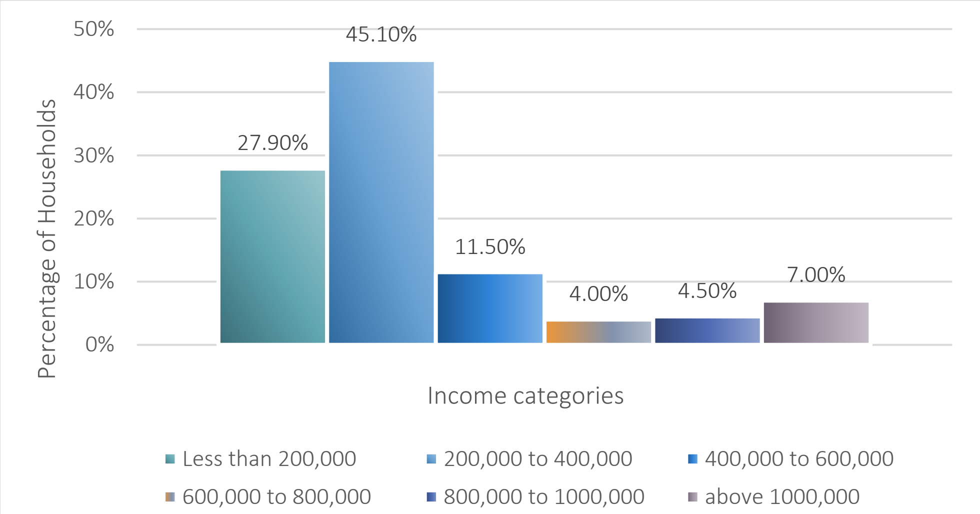
- GM = gross margin (SYP/donum)
- TR = total revenue (SYP/donum)
- TVC = total variable costs (SYP/donum)

On average and for the 2022 agricultural season after the irrigation system was put into service, the income generated from 1 donum of land at the sample level was 373 639 SYP.[2] For better demonstration, the income was divided into groups as can be seen in Figure 13. The majority of the study sample (73.1 percent) had an income of up to 400 000 SYP per 1 donum, 11.5 percent earned between 400 000 and 600 000 SYP per 1 donum, while for higher income groups (600 000–1 000 000 SYP) the percentages ranged from 4 to 7 percent.[3]

[2] The official exchange rate in 2021: 1 USD = 2 500 SYP (Central Bank of Syria, 2022).

[3] Income generated by agricultural land is subject to many factors including the type of cultivated crops, the investment of land in various agricultural seasons (summer, winter and in between seasons), agricultural practices adopted by farmers, and the quantity, quality and prices of inputs among others.

Figure 13. Income per unit of land (donum) at the sample level (SYP/donum)



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study.

The results also suggest a positive relationship between income generated by a unit of land and the landholding group with a significant coefficient of the chi-square test (Table 22) and this was supported by a Phi test which indicates the strength of association (Table 23).

Table 22. Chi-square test of association between income per land and holding group

	Value	df	Asymptotic significance (2-sided) *
Pearson chi-square	48.105	10	.000
Likelihood Ratio	48.133	10	.000
Linear-by-Linear Association	3.643	1	.056
No. of valid cases	401		

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

* Significance value below 0.05 indicates a significant association.

Table 23. Strength of association between income per land and holding group (symmetric measures)

Nominal by Nominal	Value	Approximate significance*
Phi	.346	.000
Cramer's V	.245	.000
No. of valid cases	401	

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

* Significance value below 0.05 indicates a significant value of the Phi test.

It was also found that the association between income and getting required irrigation water was statistically significant indicating that irrigation was associated with income as a result of increased production and productivity. A similar result was obtained when testing the association between income and food security.

Food security

Based on the 2022 Humanitarian Needs Overview report, it was estimated that 12 million people were food insecure with 1.9 million at risk of being food insecure in the Syrian Arab Republic in 2021. In Homs governorate, it was estimated that the number of food insecure people reached 934 118 people, equivalent to 61.43 percent with 18 461 food insecure people in Al-Rastan district, including Al-Rastan and Talibseh subdistricts (OCHA, 2022).

In this study, food security was estimated for the interviewed households based on the food consumption score (FCS).

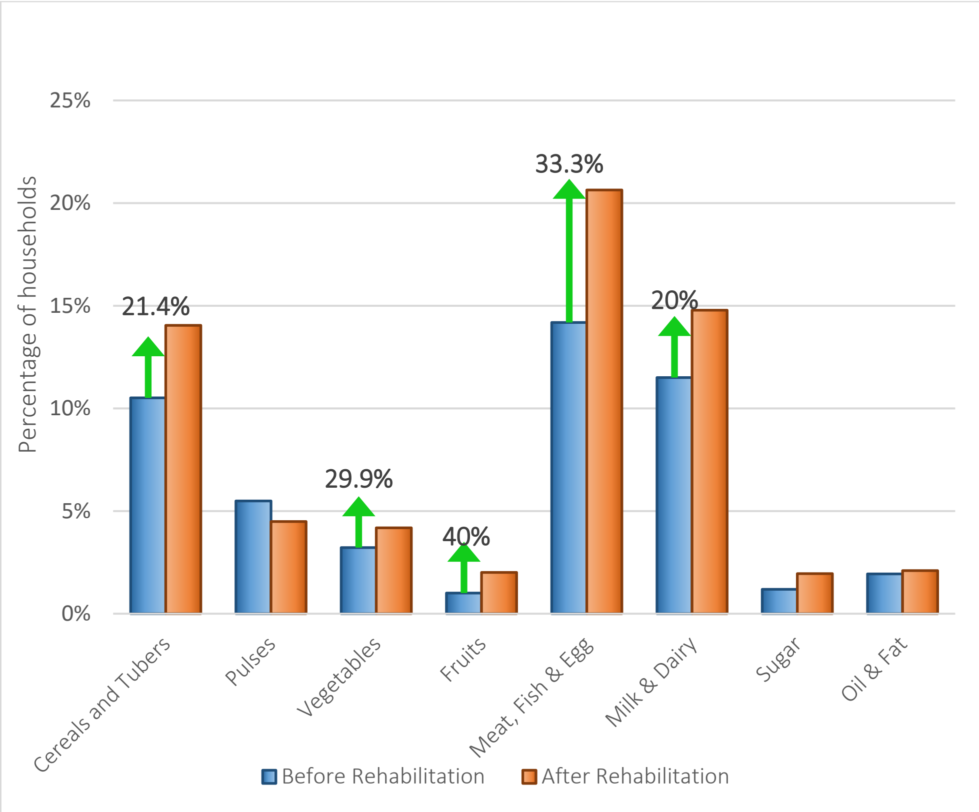
Food consumption score

FCS measures the adequacy of household food consumption and classifies it under three categories: acceptable, borderline and poor. Poor food consumption in the Syrian Arab Republic corresponds to a diet that is dominated by cereals, complemented by sugar and vegetable oil with very limited access to vegetables or sources of protein. Poor and borderline food consumption is associated with limited access to food in terms of both limited quantity and diversity.

The FCS was calculated for the study sample with reference to the period before rehabilitation. Figure 14 shows that the poor and borderline consumption groups have declined by 4 and 7 percent respectively while the acceptable group increased by 11 percent compared to before rehabilitation.

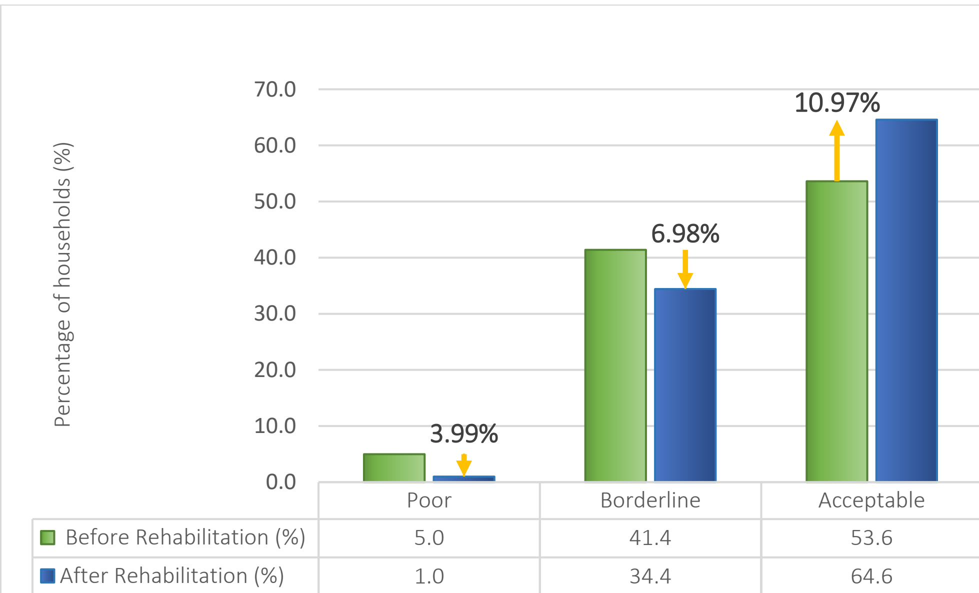
The positive impact on food security was due to more agricultural productivity in terms of crop and livestock production. This contributed to more consumption of highly nutritious food groups such as fruits, vegetables, meat, milk and dairy products by the local community. Figure 15 demonstrates the change in the consumption of different food groups at the sample level after rehabilitation.

Figure 14. Change in food groups consumption at the sample level before and after rehabilitation



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Figure 15. Change in consumption of different food groups at the sample level before and after rehabilitation



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Food security by gender

Distribution of men- and women-headed households within the food security groups, based on FCS, revealed that 38 percent of women-headed households fall within the borderline food security group compared to 33 percent of men-headed households. The majority of men- and women-headed households fall within the acceptable group, 65 and 62 percent respectively. Table 24 shows frequencies and percentages of men- and women-headed households within the three food security groups.

Table 24. FCS by the gender of the household head

FCS	Total	Percentage (%)	Male		Female	
			count	%	count	%
Acceptable	259	64.6	223	55.6	36	9.0
Borderline	138	34.4	116	28.9	22	5.5
Poor	4	1.0	4	1.0	0	0
Total	**401**	**100**	**343**	**85.5**	**58**	**14.5**

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Food security by landholding groups

To capture the relationship between landholding size and food security, the test of association was conducted. The test results suggested a significant positive correlation between the tested variables indicating that farmers with larger holding sizes are more likely to be food secure. This was more visible for the 5 to 15 donums group, see Table 25.

Table 25. FCS by the landholding groups

FCS	4 donums or less	5 to 15 donums	above 15 donums	Total
Poor	0	1	3	**4**
Borderline	56	58	24	**138**
Acceptable	33	174	52	**259**
Total	**89**	**233**	**79**	**401**

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Food security by livestock activities

Many farmers raise livestock to support their source of income and provide them with certain food groups (meat and dairy products). The relationship between food security (based on FCS) and each livestock type (cattle, sheep and goats) was tested through the chi-square test of association and was found significant (significance of chi-square coefficient is less than 0.05) and positive (based on the Phi test value). This suggests farmers raising cattle, goats or sheep along with agricultural production are more likely to be food secure. On the other hand, the relationship between food security and both poultry and beekeeping was found insignificant, see Table 26.

Table 26. FCS by livestock activity

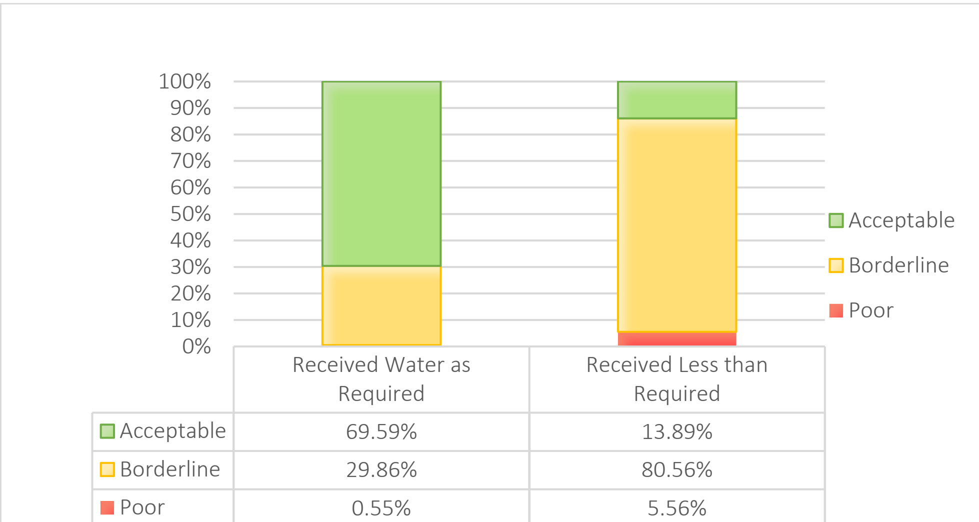
FCS	Cattle		Sheep		Goats	
	Yes	No	Yes	No	Yes	No
Poor	0.3%	3.2%	0.3%	2.9%	0.8%	2.5%
Borderline	30.8%	46.2%	26.5%	57.3%	29.4%	80.0%
Acceptable	68.8%	50.5%	73.2%	39.8%	69.8%	17.5%

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Food security and access to irrigation water

To measure the relationship between food security and the received irrigation water based on crop water requirements, the chi-square test of association was conducted between the FCS (the access pillar of food security) and the irrigation water received by farmers (access to reliable irrigation water). Results showed that, relatively, farmers who received the irrigation water as scheduled based on crop water requirements had higher FCS (acceptable FCS) compared to farmers who received less irrigation water than required (borderline or poor FCS), see Figure 16. The statistically significant relationship indicates the positive impact of access to irrigation water on the status of food security, which can be linked to increased income and production, and hence, the significant contribution of irrigation water to the improvement of food consumption and consequently, the food security status in the study area.

Figure 16. FCS by crop water requirements



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Land value

It was reported that before rehabilitation, and as a consequence of the absence of irrigation, previously irrigated lands were shifted to rainfed cultivation with some exceptions where producers used private wells.

The productivity of the land was relatively low, and the costs of investment were too high. Therefore, the land value and prices declined with the decline in productivity. Currently, due to opening access to irrigation water after rehabilitation, the productivity of land has increased which led to an increase in the land value.

The estimated value of 1 donum of land in the Talbiseh subdistrict prior to rehabilitation ranged from 7 million to 10 million SYP (depending on location), while it is estimated now for an irrigated land in the same area at 20 million to 30 million SYP (depending on location) indicating that the prices of land have almost tripled. In Al-Rastan subdistrict, the average price for 1 donum of land was estimated at 3 million SYP before rehabilitation. Currently, it is estimated at 13 million SYP and could reach 25 million as it gets closer to Qattina dam or Al-Assi River within the targeted area in Al-Rastan.

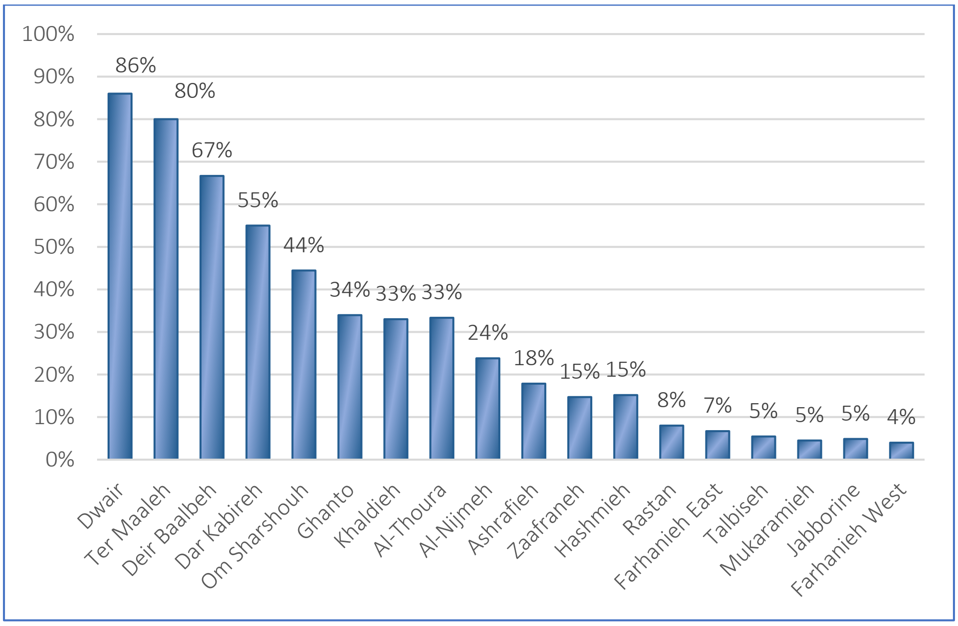
Similarly, the rental prices have changed; while they used to range from 25 000 to 35 000 SYP for 1 donum, it is estimated now to reach 150 000 to 200 000 SYP for irrigated lands and it is currently estimated at 30 000 to 60 000 SYP for rainfed lands.[4]

Returnees

Based on data collected at the village level within the study area, the total number of returnees (farmers or working in farming activities) was estimated at 4 108 households by May 2022. Most of the returnees relied on agriculture for their livelihoods and had deserted their lands when irrigated agriculture was disrupted in the early stages of the conflict in the country. The access to water for irrigation allowed returnees to engage in agriculture and agricultural-related activities, which provided them with a sense of stability that was lacking before the rehabilitation of the irrigation network. The emerging economic activities in the area further supported the returnees as an indirect effect of the rehabilitation. Figure 17 shows the percentage of returnees by village.

[4] Land prices have been relatively affected by the economic situation and the rise of prices at national level.

Figure 17. Returnee households after rehabilitation (percentage by village)



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Marketing

The marketing of agricultural, livestock and dairy products in northern rural Homs (Al-Rastan district) has many routes depending on the type of product and the proximity of the market to the production site. Before 2010, many agricultural products used to be transported to Al-Hal central market in Damascus. This almost stopped during the crisis, and it is very limited now due to the high costs of transportation. The current marketing for different products can be summarized as follows:

- Wheat has the larger share of production and is mainly sold to the Syrian Public Establishment for Grains as a part of the strategic plan at the national level. Though some farmers sell their products to the private sector to make more benefits. The establishment is almost 20 km from Al-Rastan.
- Spices such as anise, cumin, black seed and coriander are major crops in the area and the produce of these crops is mainly sold directly from the farm to traders (90 percent of the produce) who mainly monopolize the trade of these products in Homs and in the export markets. The farmers reported that traders are controlling prices and they receive significantly lower prices than the market price and consequently, the process is more profitable for traders than for the farmers themselves.
- A few grain sorting facilities are distributed in the area and in some cases, farmers use them to prepare their produce for selling benefiting from the added value but still they find the prices not fair enough. This requires looking

deeper into the issue in order to provide a suitable environment for farmers to benefit more from their produce.

- For the other crops sown in the area, mainly summer and winter vegetables, the produce is transported and sold in Al-Hal central market in Homs city which is almost 20 km from Al-Rastan. Recently and after rehabilitation, a new local market was established to sell agricultural produce in Al-Rastan which is closer (10 km from most villages) saving some transportation cost. In this regard, farmers reported having an issue with the constantly rising fuel prices which makes the process expensive and consequently less profitable.
- For milk and dairy products, before the crisis, local produce used to be transported and sold in Homs, Hama and Aleppo. Currently, there are a few local small-scale facilities in the area where milk is processed, and dairy products are produced and sold to the local communities. The main issues in marketing dairy products are the lack of power, high prices of fuel and lack of cooling facilities.
- As for the livestock production (cattle and sheep), it is mainly sold through local livestock markets in Deir Baalbeh, Zaafranehn and eastern Talbiseh which are almost 10 km from producing areas. The main issue for selling livestock is the high prices of fuel and transportation costs which drive producers to sell their produce in local markets at relatively lower prices.

Marketing directions

The main directions for marketing agricultural production and percentages of using these markets according to the villages covered by the rehabilitation intervention are summarized in Table 27.

The marketing directions were captured at the sample level for the cultivated crops and are presented in Tables 28 and 29. For wheat, 93.94 percent and 6 percent of farmers respectively sell their produce to the Syrian Public Establishment for Grain and General Organization for Seed Multiplication. Some farmers also sell a part of their produce in the local market and to local traders. For barley, 66.67 percent sell their produce to the Syrian Establishment for Grain, and 44.45 percent sell their produce directly to livestock breeders, see Table 28.

Table 27. Main marketing directions in the study area

No.	Village	Local Al-Hal market in Al-Rastan	Central Al-Hal market (Homs city)	Other markets
1	Al-Rastan, Tiebo, Al-Tliel, Al-Musafer, Zaafaraneh, Ghunatah	85%	10%	5%
2	Talbiseh, Om Sahshouh, Al-Mukarramieh, Al-Hashmieh, Farhanieh (east and west), Jabbourine	60%	35%	5%
3	Ashrafieh, Al-Mukhtarieh, Al-Ghanto, Teir Maaleh	10%	85%	5%

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

Table 28. Marketing directions for cultivated wheat and barley at the sample level

	Syrian Public Establishment for Grain	General Organization for Seed Multiplication	Local market	Local traders	Livestock breeders
Wheat	N = 276 93.94%	N=18 6.06%	N = 21 7.07%	N= 12 4.04%	–
Barley	N= 12 66.67%	–	–	–	N= 8 44.45%

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

As for the other cultivated crops, the marketing directions differed between the local market, Al-Hal central market and local traders (especially in the case of spices). Main marketing directions for cultivated crops are presented in Table 29 with estimated distance by interviewed farmers.

Table 29. Marketing directions for cultivated crops at the sample level

	Local market	Distance (km)	Al-Hal Central market	Distance (km)	Local traders
Anise	N= 36 36.73%	5 to 10 (Mean=7)	–	–	N= 68 69.39%
Vegetables	N= 41 25.95%	1 to 18 (Mean=12)	N = 117 74.05%	2 to 10 (Mean=5.2)	–
Soybean	N= 40 64.52%	2 to 6 (Mean=4.5)	–	–	N= 22 35.48%
Black seed	N= 32 54.24%	2 to 15 (Mean=5.8)	–	–	N= 27 45.76%
Potato	N= 22 55%	2 to 8 (Mean=4.5)	N= 17 42.5%	10 to 18 (Mean=14.2)	–
Coriander	N= 31 60.78%	5 to 10 (Mean=5.8)	–	–	N= 20 39.22%
Cumin	N= 3 15.79%	5 to 10 (Mean=6.7)	–	–	N= 16 84.21%
Sunflower	N= 18 56.25%	5 to 10 (Mean=6.4)	–	–	N= 14 43.75%
Yellow corn	N= 18 78.26%	3 to 8 (Mean=5.2)	–	–	N= 5 21.74%
Sesame	N= 9 60%	3 to 6 (Mean=5.1)	–	–	N= 6 40%
Onion	N= 2 75%	3 to 5 (Mean=4.5)	N= 6 25%	10 to 16 (Mean=13.5)	–
Garlic	N= 5 100%	5 to 11 (Mean=7)	–	–	–

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample, SPSS output.

Employment opportunities

Since access to irrigation led to an increase in the cultivated areas, seasonal employment opportunities have become more available. Labour opportunities generated by the rehabilitation (including family and hired labour) were calculated based on the labour requirements for the additional areas brought under cultivation due to rehabilitation and in accordance with the cropping season requirements, see Table 30.

Table 30. Generated labour opportunities based on increased areas of production

Cropping season	Increased cultivated area (donum)	Required working days per 1 donum	Average wage per worker per day (SYP)	Value of generated labour opportunities (USD)
Summer	7 309	30	7 500	657 810
Winter	21 297	60	7 500	3 833 460
In between seasons	12 082	20	7 500	724 920

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study sample.

It was reported that agriculture-related activities also increased and provided additional employment opportunities for local communities. The rehabilitation contributed to an increase in the marketing of pesticides, chemical fertilizers and seeds, especially for the other crops that returned to the area with the return of irrigation water.

Agriculture providing seasonal employment opportunities for local communities

© Mazen Haffar

© Mazen Haffar

Intervention cost analysis

Economic analysis of an intervention aims at assessing the additional income to the community resulting from the intervention implementation. The benefits were calculated based on farm income for additional areas brought under cultivation as a result of the rehabilitation. Costs of cultivation, farm-gate price for produce and the official exchange rate were considered (with reference to the 2021 cultivation season).

Intervention benefits

Benefits were estimated based on the increased cultivated areas post-rehabilitation and the cropping patterns (including summer, winter and other crops). For this purpose, average gross margins (GM) were estimated for each crop (revenue after subtracting variable costs). The benefits were estimated in SYP and converted to USD for the sake of comparison, Table 31.[5]

Table 31. Generated benefits of the intervention based on agricultural production (three seasons, one year, after rehabilitation works)

Cropping season	Crop	GM/ total increased cultivated area post-rehabilitation (USD)	Subtotal (USD)	Total (USD)
Summer crops	Sunflower	95 052	959 473	5 060 035
	Yellow corn	63 925		
	Onion	317 131		
	Sesame	86 610		
	Vegetables	396 754		
Winter crops	Wheat	315 444	2 615 618	
	Black seed	348 975		
	Anise	497 997		
	Coriander	69 388		
	Garlic	370 207		
	Onion	129 343		
	Potato	496 929		
	Vegetables	387 336		
Other crops	Soybean	161 013	1 484 944	
	Yellow corn	132 519		
	Fall potato	289 011		
	Sunflower	358 482		
	Vegetables	543 918		

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study.

[5] The official exchange rate in 2021: 1 USD = 2 500 SYP (Central Bank of Syria, 2022).

Intervention costs

The intervention costs were calculated at activity level and are expressed in USD, see Table 32. These mainly included:

- rehabilitation of Al-Rastan irrigation network;
- capacity building programme; and
- overhead costs (technical staff, technical support, programme management unit, administrative costs), logistics and operations.

Table 32. Intervention costs at activity level

Main activity	Activity	Cost per activity	Subtotal (USD)	Total (USD)
Rehabilitation of Al-Rastan irrigation network	Rehabilitation of the local irrigation network and related infrastructure	26 451	504 931	591 061
	Maintenance works for the concrete lined on-farm irrigation network and rehabilitation of five irrigation management centres	354 480		
	Rehabilitation field branch canals (1, 2, and 3), tertiary canals, and Ghneih Al-Assi Roman irrigation canal	124 000		
Capacity building programme	Training of trainers	3 740	21 130	
	Farmers' training	14 600		
	Workshop	2 790		
Overhead costs	Overall supervision, technical supervision, technical support, coordination, logistic support		65 000	

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study.

Return on investment

For the irrigation intervention in Al-Rastan, return on investment was used as an indicator of the intervention's profitability. Return on investment (ROI) covers the cost of the intervention subject of the study (rehabilitation of Al-Rastan irrigation network) and the benefits based on the additional cultivated area in 2021 compared to 2020 as a result of providing access to water.

This indicator did not include the operation and maintenance costs borne by water authorities regarding the main and secondary canals.

The water is usually pumped from Qattina Lake into the irrigation network only if the lake's water storage is below the dead capacity (50 million m^3) and only in cases when summer crops require further irrigation water at the end of the summer season (when the water level in the lake is not high enough to feed the irrigation network with the required discharge). Otherwise, water flows from the lake into the irrigation network by gravity. In 2021, however, the water storage was good (about 200 million m^3) and there was no need to pump water from the lake anyway.

The ROI was calculated based on intervention costs and estimated benefits according to the following formula:

$$ROI = \frac{Gain\ from\ investment - Cost\ of\ investment}{Cost\ of\ investment} * 100$$

ROI = (5 070 398 – 591 061) / 591 061 = **756 percent**

This result indicates that the benefits of the intervention outweighed the costs, which means that the intervention was highly profitable considering that the benefits were calculated for the first agricultural season after rehabilitation.

Results of the study of WUAs and related indicators

Analysing the performance of WUAs determines the extent to which these associations are effective in performing their roles. It reveals the effectiveness of the capacity building programme and helps identify constraints and opportunities for improved performance. This, in turn, contributes to sustainability of resources and improved production. Several performance indicators were assessed through WUAs records, group discussions, key informants and beneficiaries' responses to reflect governance improvement. These include:

- commitment to irrigation schedules (enforcement of water distribution schedule, planned versus actual);
- fair distribution of irrigation water considering the land size and crop water requirement;
- management, operation and maintenance;
- coordination with public institutions and application of division of labour between the public and private organizations; and
- water fee collection and use.

The performance of the WUAs was evaluated by monitoring their commitment to managing the irrigation scheme and the planned irrigation schedules. Some good practices were observed while some challenges persisted. Therefore, as a first attempt of its kind within such a relatively big size irrigation scheme, further monitoring and support for the WUAs are recommended. This should enhance the capacities of WUAs in performing their roles as planned and as described in the below background.

Background

FAO addresses the concept of WUAs in all the implemented projects to promote efficient management of water resources by local communities and fair distribution of irrigation water among beneficiaries.

One important role of the WUA is to rationalize and manage irrigation water to achieve preservation and sustainability of agricultural water resources and raise the technical and economic efficiencies of their use. A participatory approach is adopted to strengthen the role of WUAs to achieve the best management of water resources in a way that achieves fair distribution of water among all users according to the crop water requirements and land size.

In parallel with the implementation of the rehabilitation works, and to ensure the implementation of a sustainable field irrigation management plan, six WUAs were established in Al-Rastan, see Table 33. A management board of five farmers was elected by the members of each WUA comprising a head of the WUA, assistant and secretary, accountant, operator and maintenance responsible member. The main role of the WUA is to improve water delivery, increase crop production and provide farmers with a real chance to be involved in the process of irrigation management. WUA members should ensure that the elected management board performs its responsibilities to achieve the targets of the WUA. The main responsibilities of the WUA management board as agreed upon with farmers and water authorities are summarized as follows:

- contact the water authorities to learn about the agricultural irrigation plan for each season;
- work with the extension unit or FAO experts to get the updated irrigation schedules according to the crop water requirements to best perform the water distribution process;
- hold frequent meetings with the WUA members to discuss irrigation issues and keep records of the irrigation schedules. The discussions may also describe the cultivation and irrigation plans and estimated production;
- determine proper timing for seasonal maintenance, estimate costs and plan for maintenance implementation;
- monitor the performance of the irrigation field infrastructures such as gates and regulators and any infringement or fault on the irrigation network to prevent water losses;
- ensure that irrigation begins from the farthest to the nearest properties according to the agreed irrigation schedules;
- prevent the use of drainage water for irrigation unless approved through a technical study of the concerned water and crops;
- communicate the performance of the WUA in terms of the irrigation management plan, financing issues, operation and maintenance of the irrigation system to the WUA members for evaluation and improvement. This includes presenting an overall picture of the progress made in field irrigation management and whether a fair distribution plan was successfully implemented or not. Challenges and lessons learned should be discussed to improve the performance of the WUA in the next seasons;
- coordinate with neighbouring WUAs to exchange knowledge and improve water governance; and
- conduct regular field meetings with farmers to learn more about their cultivation plans, faced difficulties, etc.

A training for the WUA management boards was conducted during implementation. The training focused on the role of the WUA and the WUA management board responsibilities, and the main tasks of the management board members.

A training for farmers including members of the WUAs was also conducted and included the following topics:

- components (structure) of the surface irrigation system (primary, branch, sub-branch and tertiary canals) and small-scale efficient irrigation systems, in particular drip and sprinkler systems;
- crop water requirements, irrigation programmes and irrigation scheduling;
- operation and maintenance of the irrigation systems; and
- efficient irrigation techniques (advantages, components, operation, maintenance, etc.).

Table 33. WUAs established in Al-Rastan

Name of WUA	Intake No.	Discharge (L/sec)	Irrigated area (ha)	No. of members
Ghneih Al Assi	1	70	144.1	335
	2	80	179.4	
	3	70	119.9	
Teibo	3	40	130.0	60
Al Tliel	2B/3	40	275.0	75
Al-Mosafer	2B/4	40	325.0	65
Al-Khairat	2A/1	40	150.0	140
Al-Basateen	2B/1	40	200.0	105
Total			1 523.4	800

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study.

Training of the WUA management boards on irrigation management and irrigation water distribution

© FAO technical team

© FAO technical team

Strengthening water governance through WUAs

Water governance is defined as the set of rules, practices and processes through which decisions for the management of water resources and services are taken and implemented.

Engaging with the local community and stakeholders is a key principle of water governance and vital to ensure everyone has their water services in line with their rights. In this context, it was recognized that transferring the management of field irrigation to farmers is key to achieving good water governance. This process is being implemented mainly through the established six WUAs and considering three integrated governance levels:

1. The first level is established between water authorities, agriculture authorities and the WUAs management boards. It includes:
    - irrigated area is determined at the village level;
    - planned areas for cultivation with summer, winter and other crops are determined;
    - crop water requirements are calculated for planned crops;
    - evaluation of the water source (Qattina dam) is conducted to determine water availability;
    - irrigation programme and agriculture plans are finalized considering water availability and the crop water requirements; and
    - WUAs management boards exchange knowledge, needs, integrated agricultural plans, irrigation plans, difficulties, etc. with line authorities.

    During the conducted survey and field meetings, it was confirmed through the first level that for 2021, the retained water in Qattina dam allowed for implementing the agricultural plan. Therefore, the agricultural plan was fully implemented with irrigation covering requirements for all cropping seasons (summer, winter and other crops).

    However, in 2022, the agricultural plan was revised, and priority was given to the winter cropping season (mainly wheat) as the precipitation rates were not sufficient to cover all cropping seasons. The irrigation season started on 17 April 2022 and lasted for 2 months compared to almost 6 months in 2021 (from 3 April to 30 September 2021).

    The above information was transferred to farmers through the second governance level.

2. The second level is established between water authorities and farmers through the WUAs, mainly the management boards.

    At the level of the secondary branched canals, the water committees establish meetings with the water management boards of the WUAs to discuss with them the irrigation programme and advise for developing irrigation schedules accordingly. Before the irrigation season starts, the irrigation programme and irrigation schedules for farmers are prepared supported by local technicians trained by FAO and/or related local establishments such as the General Commission for Scientific Agricultural Research. The WUAs then, manage the distribution of the irrigation water according to the updated irrigation schedules.

3. The third governance level is established between WUAs and beneficiaries for irrigation scheduling at the level of tertiary canals. The WUAs management boards meet with farmers to discuss irrigation schedules and distribution of irrigation water according to plans confirmed with the water and agricultural authorities. During the field visits and the discussion with the local community, it was confirmed by farmers and WUAs members, that the WUAs management boards have started performing their responsibilities effectively. They managed the maintenance of the irrigation canals before the start of the irrigation season in coordination with the WUA's members. Farmers agreed to maintain the field irrigation canals or jointly bear costs when needed. The WUAs members volunteered to monitor the distribution of irrigation water and succeeded in resolving raised issues among farmers. The authorities are informed when technical assistance is required to ensure the efficiency of water delivery and in any case where a strict official action is required.

Meeting with WUAs representatives to discuss irrigation management measures

© FAO technical team

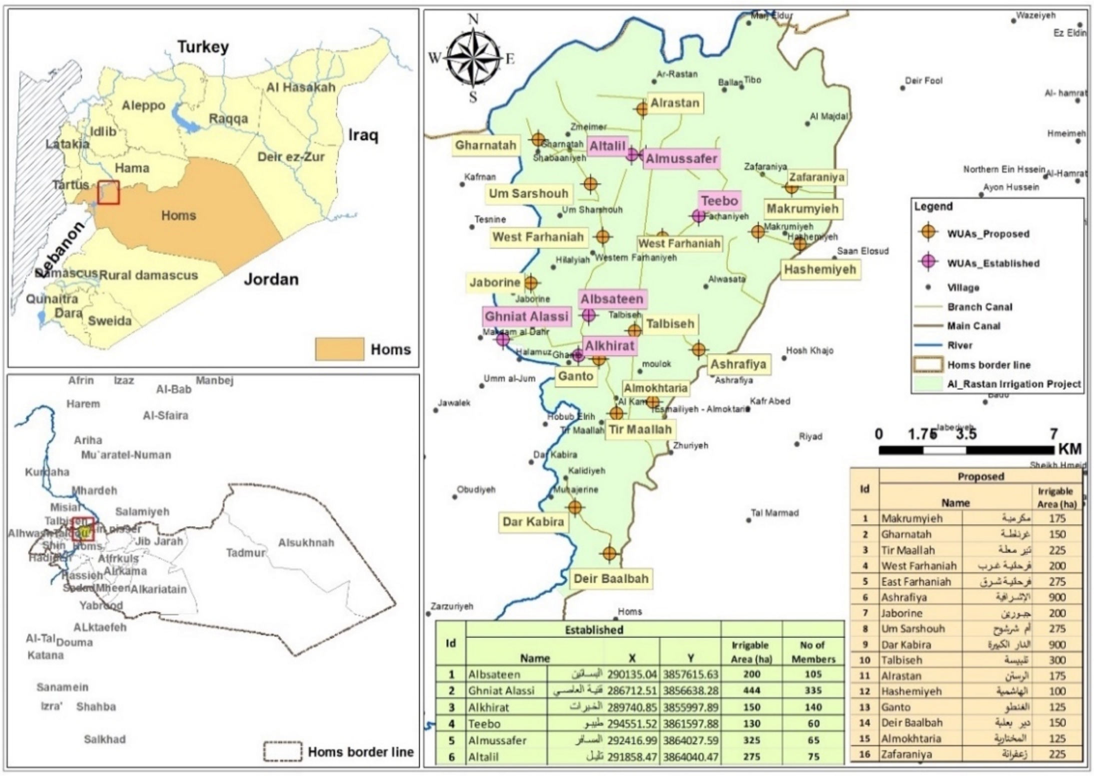
Meeting with local authorities to discuss water governance measures

© FAO technical team

Drawing on the experience of the already established WUAs, and through the field visits to Al-Rastan area and meeting with farmers, it was observed that farmers were interested in being involved in WUA activities. Therefore, a study was conducted to explore the potential of establishing new WUAs on the sub-branched canals. Hence, sixteen locations for new WUAs were proposed to cover an estimated irrigation area of 4 475 ha, see Figure 18 and Table 34).

A field mission was conducted, and several meetings were held with local communities including women to explore feasibility on the ground and to support this initiative. Many farmers were already encouraged by the experience of the previously established WUAs, they were introduced to the requirements for establishment and the application process.

Figure 18. Location of the established and proposed WUAs with irrigated areas



Source: Adapted from Google Earth Engine modified by the authors.

Table 34. Proposed WUAs with intake number and irrigated area to be covered

No.	WUA name	Intake No.	Total irrigated area (ha)	No.	WUA Name	Intake No.	Total irrigated area (ha)
1	Deir Baalbeh	5	150	9	Hashmieh	3	100
2	Om Sharshouh	23	275	10	Al-Rastan	10	150
3	Jabborine	A2 1/3	200	11	Ghornata	A2/27	150
4	Al Ghanto	12	125	12	East Farhanieh	B3/7	275
5	Almkarmieh	7	175	13	West Farhanieh	A2	200
6	Tair Maaleh	4	225	14	Al Mokhtarieh	10	125
7	Al Dar Al Kabeereh	1	900	15	Zafaraneh	A3/1	225
8	Talbisah (Wasta)	17	300	16	Al Ashrafieh	13	900
Subtotal			2 350	Subtotal			2 125
Total				4 475 ha			

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study.

Management and sustainability

Sustainability of the irrigation network requires a proper management to achieve the longer-term goal of sustainable irrigation, and consequently, sustainable livelihoods. The integrated management process requires collaboration and coordination between water and agriculture authorities and farmers through WUAs and farmers unions.

Throughout the implementation of the rehabilitation activities, irrigation management was introduced in the capacity building programme as an integrated process that includes:

- determining water availability for irrigation for each season;
- preparing the irrigation networks and related infrastructures (investigating operation readiness and maintenance works) for agricultural investment;
- planning irrigated areas and calculating crop water requirements;
- setting the irrigation plan (preparing irrigation schedules and determining the starting date of irrigation); and
- follow up on implementation of the irrigation plan.

Observed measures

At the beginning of March, the water authorities calculated the water budget for Qattina dam and determined the available water for irrigation. Accordingly, the agriculture plan was proposed and agreed on with farmers including the established WUAs. One month before the beginning of the irrigation season (usually first half of April), the irrigation network with all its components was investigated and prepared to ensure a smooth operation of the system. For the observed season (winter 2021), the WUAs took initiatives and managed to maintain and clean the irrigation canals in cooperation with farmers for all tertiary and earthen field canals.

The focus group discussions and key informant interviews revealed that the results of the capacity building programme were visible in the performance of WUAs. This was through the undertaken responsibility of the management boards in operating and maintaining the irrigation networks and their structures properly. This was also supported by regular follow up, meetings and discussion about the required tasks and application of the gained knowledge. The conducted survey showed that the WUAs, to the best of their abilities, performed required maintenance of the tertiary and earthen canals which contributed to reducing water losses. They maintained some of the water gates and preserved the components of the network from being damaged or misused. Further, they were able to manage distribution of irrigation water according to irrigation schedules with minimum to no conflicts or violations within their areas.

Farmers preparing tertiary (on-farm) irrigation canals before the irrigation season

© FAO technical team

As a result of the training, some farmers adopted modern irrigation techniques for more water use efficiency

© Mazen Haffar

The WUAs management boards performed their administrative and financial tasks and conducted their regular meetings with the irrigation centres, which were also rehabilitated within the framework of the Al-Rastan irrigation intervention. They communicated with farmers to exchange expertise, discuss agriculture and irrigation good practices, maintenance works and strengthen the sense of ownership and responsibility of the irrigation network. Some challenges related to agricultural inputs and water needs were referred to authorities on farmers' behalf when required.

It was concluded that with the infrastructure rehabilitated and the enabling environment provided, farmers have been able to take management into their own hands. Some challenges still persist, however, the foundation stone has been set for an integrated management at farm level that on the longer term ensures sustainability of infrastructure, natural resources and livelihoods.

Meeting with representatives of local community

© Mazen Haffar

© Mazen Haffar

Women's participation

The participation of women was noticeable in the capacity building activities (34 percent of trainers were female and 52.8 percent of farmers were female). Women showed interest in the presented topics and were highly motivated to use the gained knowledge to support their livelihood. On the other hand, the representation of women in WUAs is still limited due to many reasons related to the cultural norms in the area, lack of awareness, and, more importantly, lack of access to land and resources.

To enhance their role in agriculture and water management, women were addressed during the study meetings and encouraged to participate in the discussions and share their views. Their inputs and suggestions were remarkable and showed their experience in cultivation and irrigation. Given the fact that women are heavily engaged in day-to-day field agriculture and irrigation works, their participation and representation in the WUAs would support improvement of field irrigation management and related decision-making in the future.

Results of the study of the intervention's impact on surface and groundwater

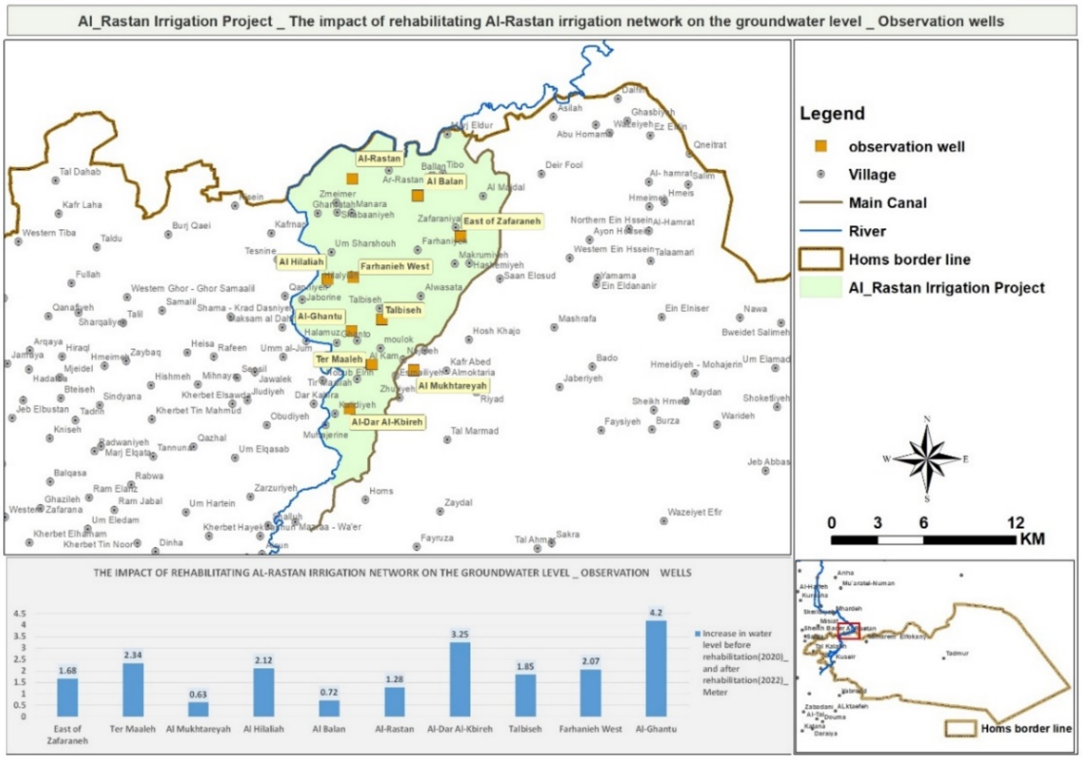
Groundwater

It was stated by farmers with private wells that the level of groundwater has increased significantly after the release of water in the rehabilitated irrigation network. Farmers no longer use only groundwater for irrigation and a conjunctive use of surface and groundwater is now practiced for summer crops. It was also observed that the groundwater abstraction rates were increased. To capture this impact, measurements of groundwater levels were taken from several locations within the study area from the Water Resources Directorate in Homs.

As can be seen in Figure 19, the increase in groundwater level ranged from 0.63 metres to 4.2 metres as an impact of the surface water flow in the rehabilitated irrigation network.

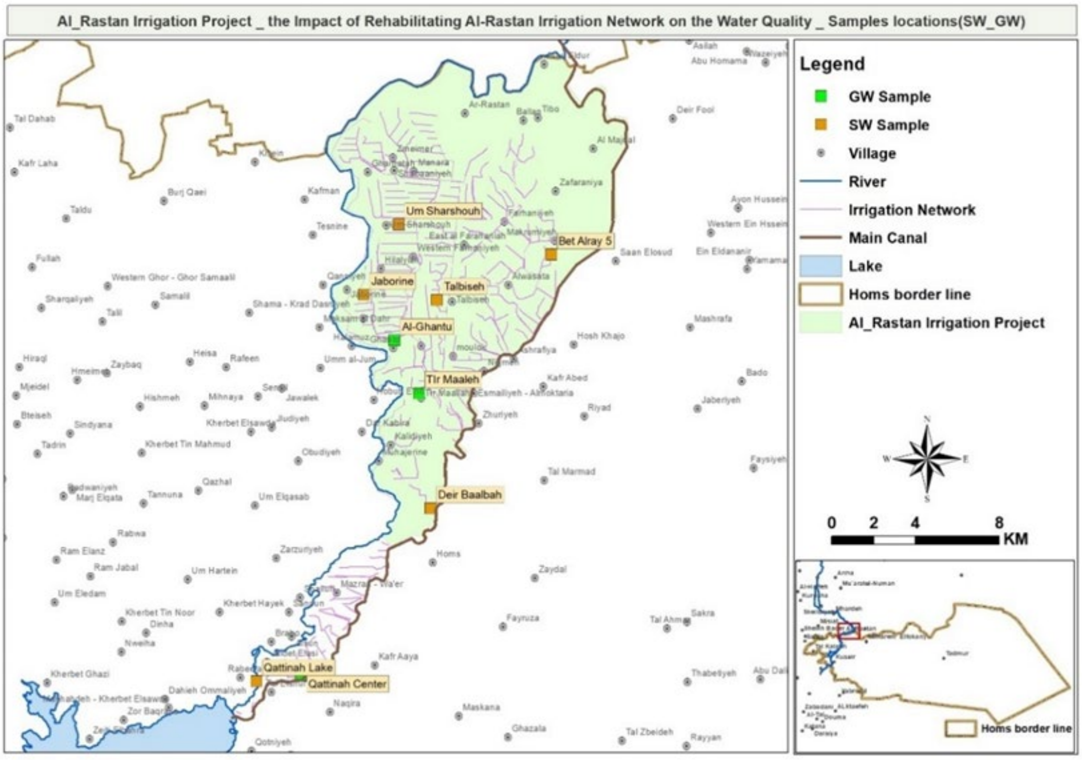
To assess the groundwater quality, groundwater samples were taken on 24 May 2022 from three locations as given in Figure 20, and a set of physical and chemical laboratory tests were conducted including temperature (C˚), turbidity (Tur), conductivity, hardness (Mg^{++} and Ca^{++}), ammonium ($NH4^+$), nitrogen ($NO3^-$ and $NO2^-$), sulphate ($SO4^-$), PH, chloride Cl^- (mg/l), phosphate ($PO4^-$) and total coliforms.

Figure 19. Location of the study of the groundwater level



Source: Adapted from Google Earth Engine modified by the authors.

Figure 20. Surface and groundwater quality sample locations of the study



Source: Adapted from Google Earth Engine modified by the authors.

It was concluded from the results that the groundwater quality complies with the Syrian standards for drinking water. This means that the groundwater can be utilized for domestic purposes as well as for agricultural activities whenever needed, see Table 35.

Table 35. Laboratory analyses results of the groundwater samples

No.	Location	T °C	pH	Tur NTU	Cond µs/cm	Hardness			NH4+ mg/l	NO3⁻ mg/l	NO2⁻ mg/l	SO4⁻ mg/l	Cl⁻ mg/l	PO4⁻ mg/l	Total coliforms
						Total	Mg++ mg/l	Ca++ mg/l							
1	Qattina	19.1	7.6	5.0	439	200	37	27	0.15	7.0	0	35	35	0.03	174
2	Teir Maaleh	19.4	7.8	2.0	715	370	79	35	0.1	5.0	0	67	74	0.20	135
3	Al-Ghanto	19.6	7.9	4.0	934	491	123	37	0.12	8.0	0	72	107	0.15	112
	Acceptable limit		8.5	5	1 500				0.5	50	0.2	250	250	0.5	1 000

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study.

Surface water

The quality of irrigation water is essential for better crop yields, maintaining soil productivity and protecting the environment. The physical and mechanical properties of the soil are very sensitive to the type and concentration of elements present in irrigation water.

With the support of Water Resources Directorate in Homs, samples of surface water were taken to assess the quality of the surface irrigation water in the rehabilitated network. Surface water samples were taken on 17 May 2022 from six locations, see Figure 20.

A set of physical and chemical laboratory tests were conducted including temperature (C˚), turbidity (Tur), and conductivity, dissolved oxygen (DO), oxygen equivalent of the organic matter (COD), biochemical oxygen demand (BOD), ammonium (NH4+), chloride (Cl⁻), hardness (Mg++ and Ca++), phosphate (PO4⁻), and nitrogen (NO3⁻). Results of the analyses showed that all measured elements were within the acceptable limits according to the Syrian standards, which indicates the suitability of water for irrigation, see Table 36.

Table 36. Laboratory analyses results of the surface water samples

No.	Location	T °C	pH	Tur NTU	Cond µs/cm	DO mg/l	C.O.D. mg/l	B.O.D. mg/l	NH4+ mg/l	Cl⁻ mg/l	Mg++ mg/l	Ca++ mg/l	PO4⁻ mg/l	NO3⁻ mg/l
1	Qattina Lake	21.2	8.3	75	423	6.0	48	25	0.5	32	40	47	1≥	32
2	Om Sharshouh	21.0	8.1	22	385	6.0	25	11	0.5	37	50	42	1≥	11
3	Jabborine	20.9	8.0	35	391	5.5	29	13	0.2	41	51	53	1≥	11
4	Deir Baalbeh	21.8	7.9	44	520	5.0	31	14	0.1	35	41	47	1≥	17
5	Al-Ramadi Canal (Talbiseh)	22.0	7.9	52	510	6.0	34	15	0.2	32	38	44	1≥	15
6	Irrigation centre No. 5	22.3	7.8	55	483	5.5	40	15	0.3	40	48	51	1≥	23
	Acceptable limit		8.5			4	100	35					1	50

Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study.

Results of the remote sensing study on the impact of the intervention on agriculture, environment and natural resources

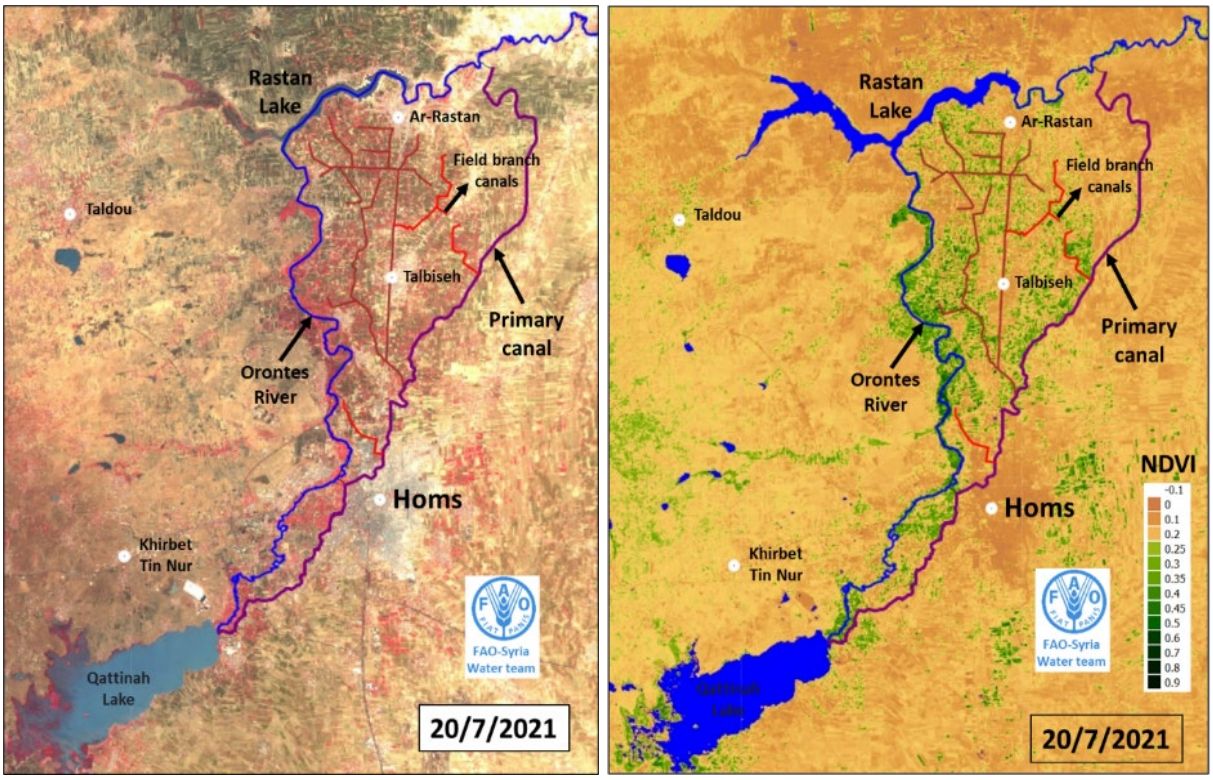
Remote sensing allows for accurate assessment and periodic monitoring of natural resources. It can be used to assess the impact of interventions in relation to agriculture (crop type, estimated yield, soil characteristics, etc.), land use, environmental aspects (such as soil degradation and soil erosion), and dynamics of hydrological processes (e.g. evapotranspiration, evaporation, transpiration, etc.).

In this study, remote sensing technique is used to assess the impacts of the implemented irrigation intervention on agriculture and natural resources through a set of related indicators. For more inclusiveness of the results, impacts were compared through four stages: pre-crisis, post-crisis, rehabilitation stage and post-rehabilitation.

Background

The Al-Rastan irrigation project is located in the north of Homs city and is bordered on the west by the Orontes River and the east by the main irrigation canal coming from Lake Qattina, see Figure 21. It includes a number of field branch canals responsible for receiving irrigation water from the primary canal and distributing it throughout the region.

Figure 21. Location of Al-Rastan irrigation project in relation to the Orontes River, Qattina Lake, Al-Rastan Lake, the primary canal, and the field branch canals (map on the left is overlaid on Sentinel-2 image (false colour), while the map on the right is overlaid on NDVI image



Source: Derived from Sentinel 2-images using Google Earth Engine modified by the authors.

Impact on vegetation cover/crop production

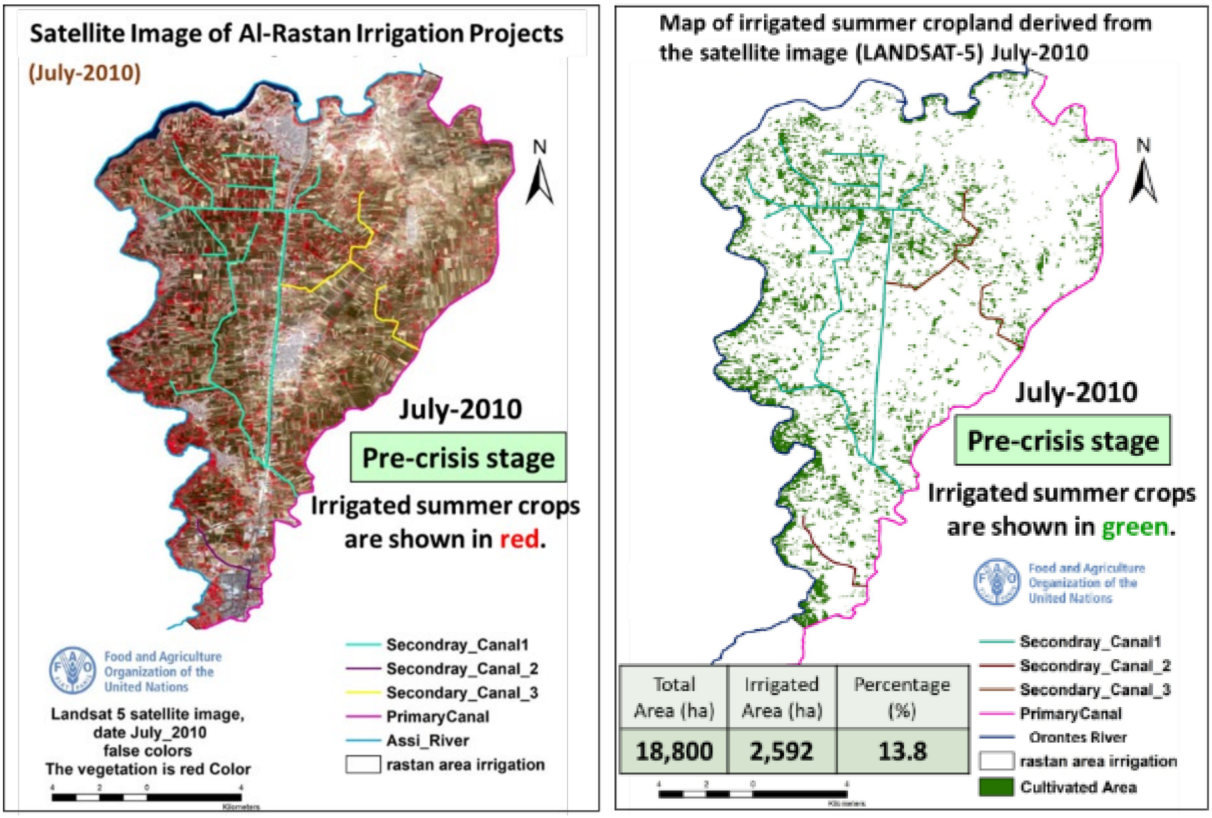
Change in the areas planted with summer crops

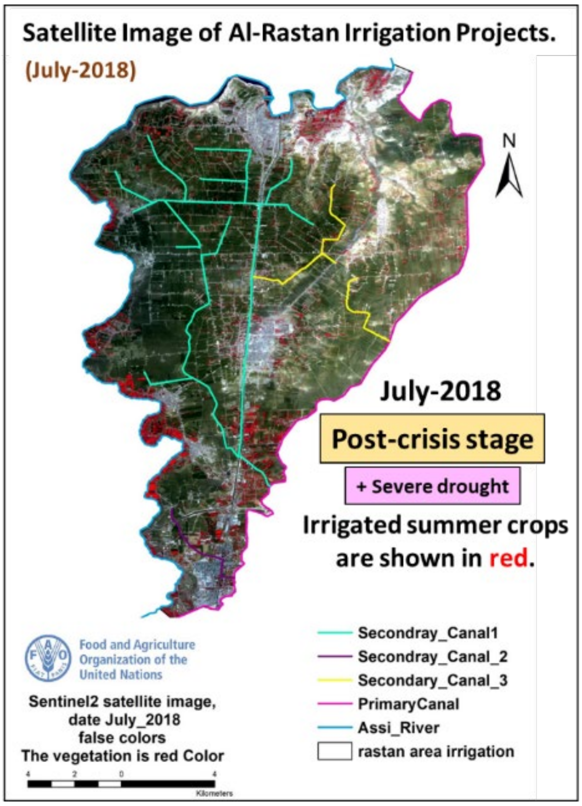
Monitoring the change in the area of irrigated summer crops using remote sensing techniques (before and after the rehabilitation of irrigation networks) may be one of the easiest, fastest and best ways to assess the impact of this intervention in Al-Rastan. The focus on summer crops stems from the fact that they are completely dependent on irrigation water for growth, as it usually does not rain in summer from May until the end of September. Thus, the presence of any summer crops requires a source of irrigation.

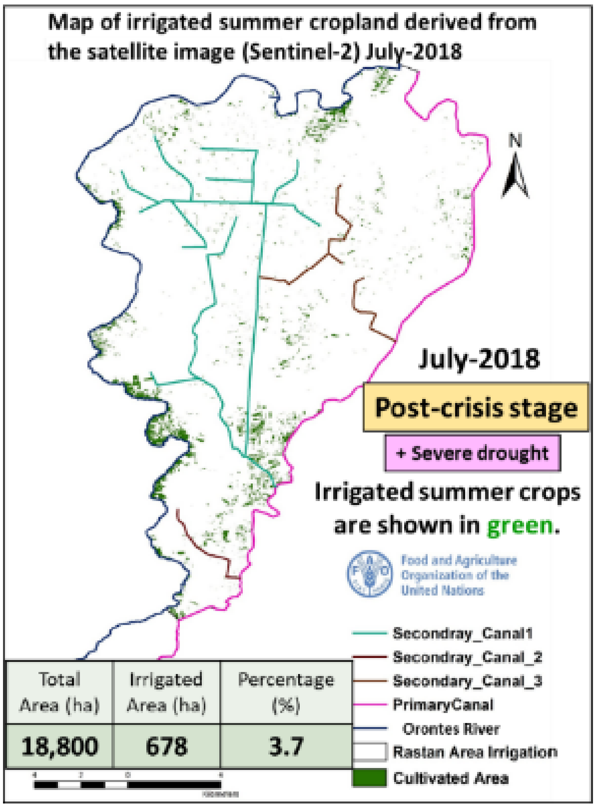
Remote sensing via satellite imagery is an excellent tool to monitor land use/land cover change because satellite images can cover large geographic extents and have a high temporal coverage “revisit period” (a relatively short time between the acquisitions of two images of the same area). Using specialized image processing software, there is a possibility to manipulate the arrangement of the spectral bands of the satellite images so that reflection information can be seen from three individual bands in a single imagery at the same time. For example, to emphasize healthy and unhealthy vegetation on Sentinel imagery, a standard false-colour composite can be created by assigning bands 8, 4, and 3 to the red, green and blue respectively. In such false-colour composite, vegetation is shown as bright red as the near infrared band (B8), in which vegetation reflects very brightly, was assigned to the red component of the composite.

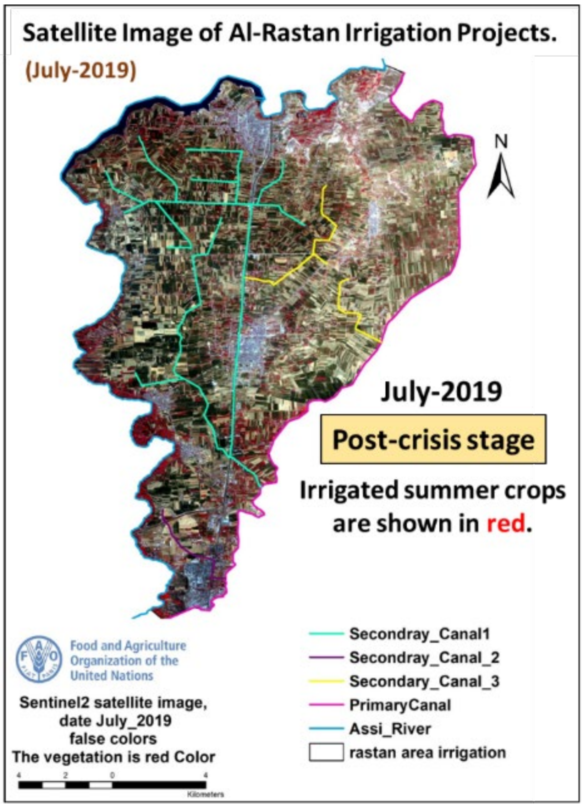
The composite images usually help in the qualitative assessment of the change in vegetation cover that occurs between different dates. However, the quantitative assessment of the change requires classifying these images and isolating the irrigated croplands in separate maps, as was done in this study. The false-colour satellite images of Al-Rastan for 2010, a pre-crisis year, and the last four post-crisis years are shown on the left side of Figure 22, while the maps of irrigated lands resulting from the classification of these images are shown on the right side.

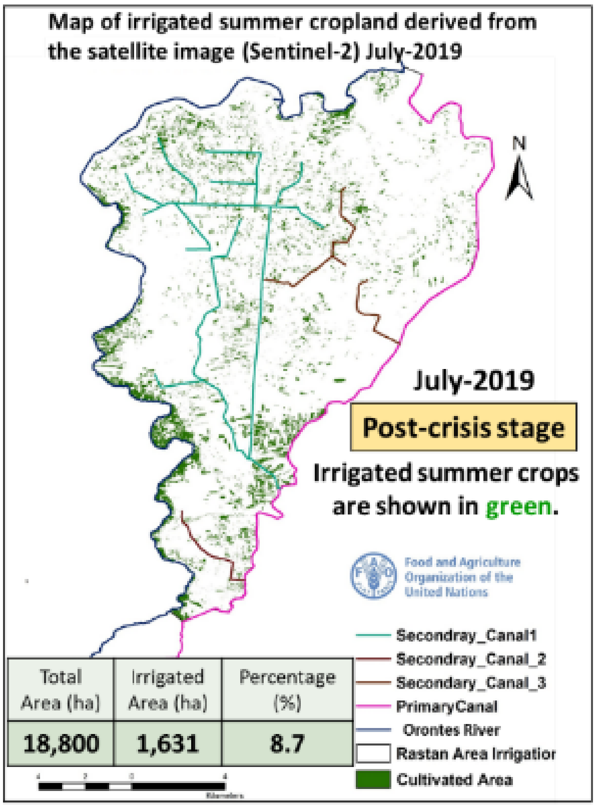
Figure 22. Maps on the left side are false-colour satellite images acquired during July of each year, while the maps on the right represent the irrigated lands derived through the classification of these images

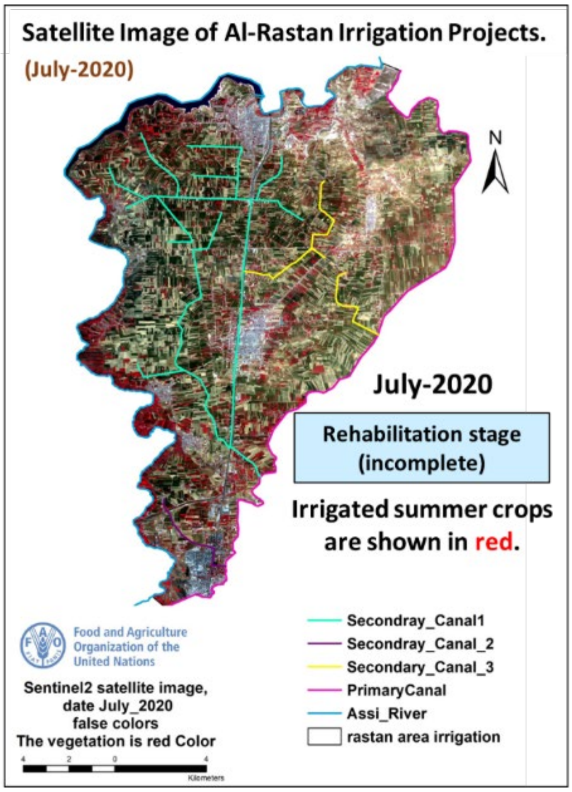


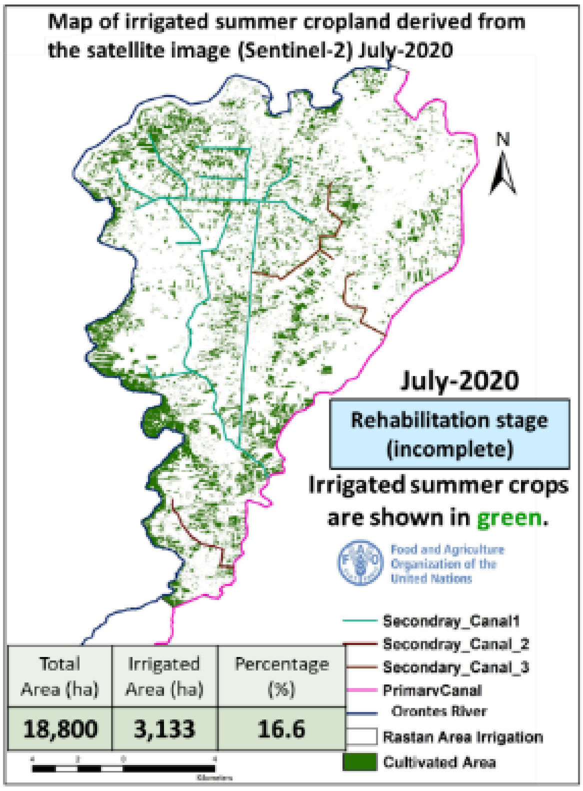

Satellite Image of Al-Rastan Irrigation Projects.
(July-2018)
N
July-2018
Post-crisis stage
+ Severe drought
Irrigated summer crops are shown in red.
Food and Agriculture Organization of the United Nations
Sentinel2 satellite image, date July_2018 false colors
The vegetation is red Color
Secondray_Canal1
Secondray_Canal_2
Secondray_Canal_3
PrimaryCanal
Assi_River
rastan area irrigation

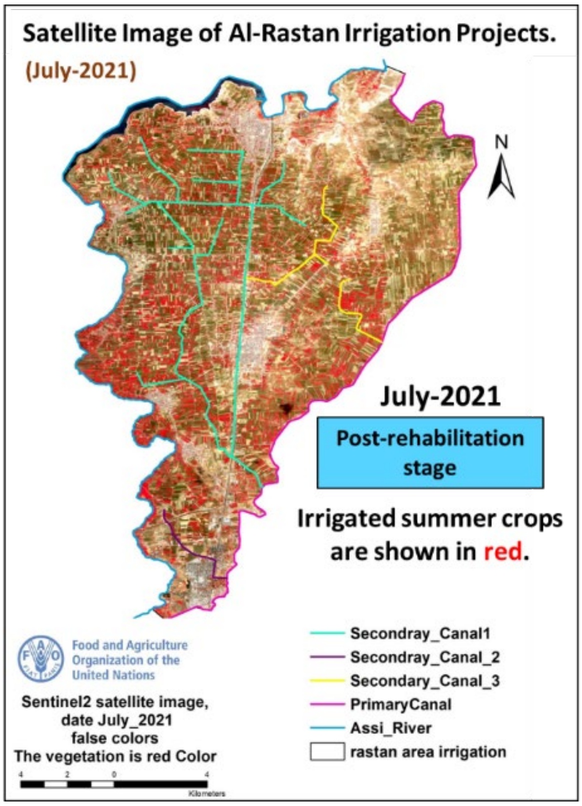

Map of irrigated summer cropland derived from the satellite image (Sentinel-2) July-2018
N
July-2018
Post-crisis stage
+ Severe drought
Irrigated summer crops are shown in green.
Food and Agriculture Organization of the United Nations
Total Area (ha) | Irrigated Area (ha) | Percentage (%)
18,800 | 678 | 3.7
Secondray_Canal1
Secondray_Canal_2
Secondray_Canal_3
PrimaryCanal
Orontes River
Rastan Area Irrigation
Cultivated Area

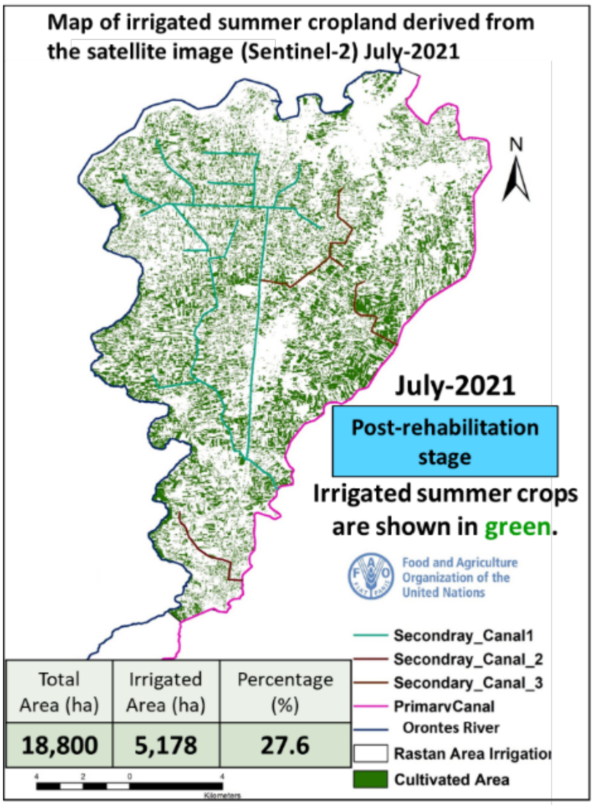

Satellite Image of Al-Rastan Irrigation Projects.
(July-2019)
N
July-2019
Post-crisis stage
Irrigated summer crops are shown in red.
Food and Agriculture Organization of the United Nations
Sentinel2 satellite image, date July_2019 false colors
The vegetation is red Color
Secondray_Canal1
Secondray_Canal_2
Secondray_Canal_3
PrimaryCanal
Assi_River
rastan area irrigation


Map of irrigated summer cropland derived from the satellite image (Sentinel-2) July-2019
N
July-2019
Post-crisis stage
Irrigated summer crops are shown in green.
Food and Agriculture Organization of the United Nations
Total Area (ha) | Irrigated Area (ha) | Percentage (%)
18,800 | 1,631 | 8.7
Secondray_Canal1
Secondray_Canal_2
Secondray_Canal_3
PrimaryCanal
Orontes River
Rastan Area Irrigatior
Cultivated Area







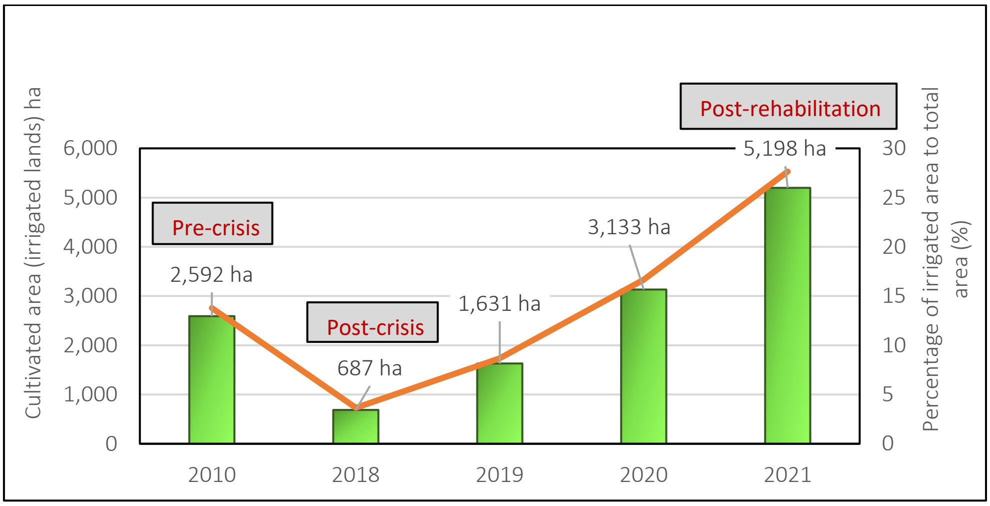


Source: Derived from Sentinel 2-images using Google Earth Engine modified by the authors.

As can be seen from the maps in Figure 22 as well as from Figure 23, the estimated area of summer irrigated crops was about 2 590 ha in July 2010 (pre-crisis phase), about 14 percent of the total area of the target region (18 800 ha). With the outbreak of the Syrian crisis in 2011, the irrigation networks that were transferring irrigation water to farmers' fields were damaged and completely out of service. This in turn negatively affected the cultivation of summer crops, which depend entirely on irrigation for their growth. As a result, the area of irrigated summer crops has decreased significantly, reaching less than 690 ha (less than 4 percent of the total area) in 2018 (post-crisis phase).

Moreover, a severe drought hit the region in 2018, which exacerbated the degradation in cultivated areas and agricultural production. The cultivated area (summer irrigated crops) witnessed a slight increase during the summer months of 2019 (a very wet year) and reached about 1 630 ha (about 9 percent of the total area). During the summer of 2020, irrigation water began to gradually return to the fields after FAO began rehabilitating the irrigation networks, which led to an increase in the cultivated area until it reached about 3 130 ha. However, a significant increase in the area of irrigated summer crops was observed during the summer of 2021 (post-rehabilitation phase), reaching about 5 180 ha (about 28 percent of the total area) since water storage capacity was high in the lake and the government supported agricultural inputs after years of no agricultural activities in the area.

Figure 23. Change in cultivated area (irrigated summer crops) over the period from 2010 (pre-crisis), through the years 2018, 2019 (post-crisis damaged irrigation networks), till 2021 (post-rehabilitation)

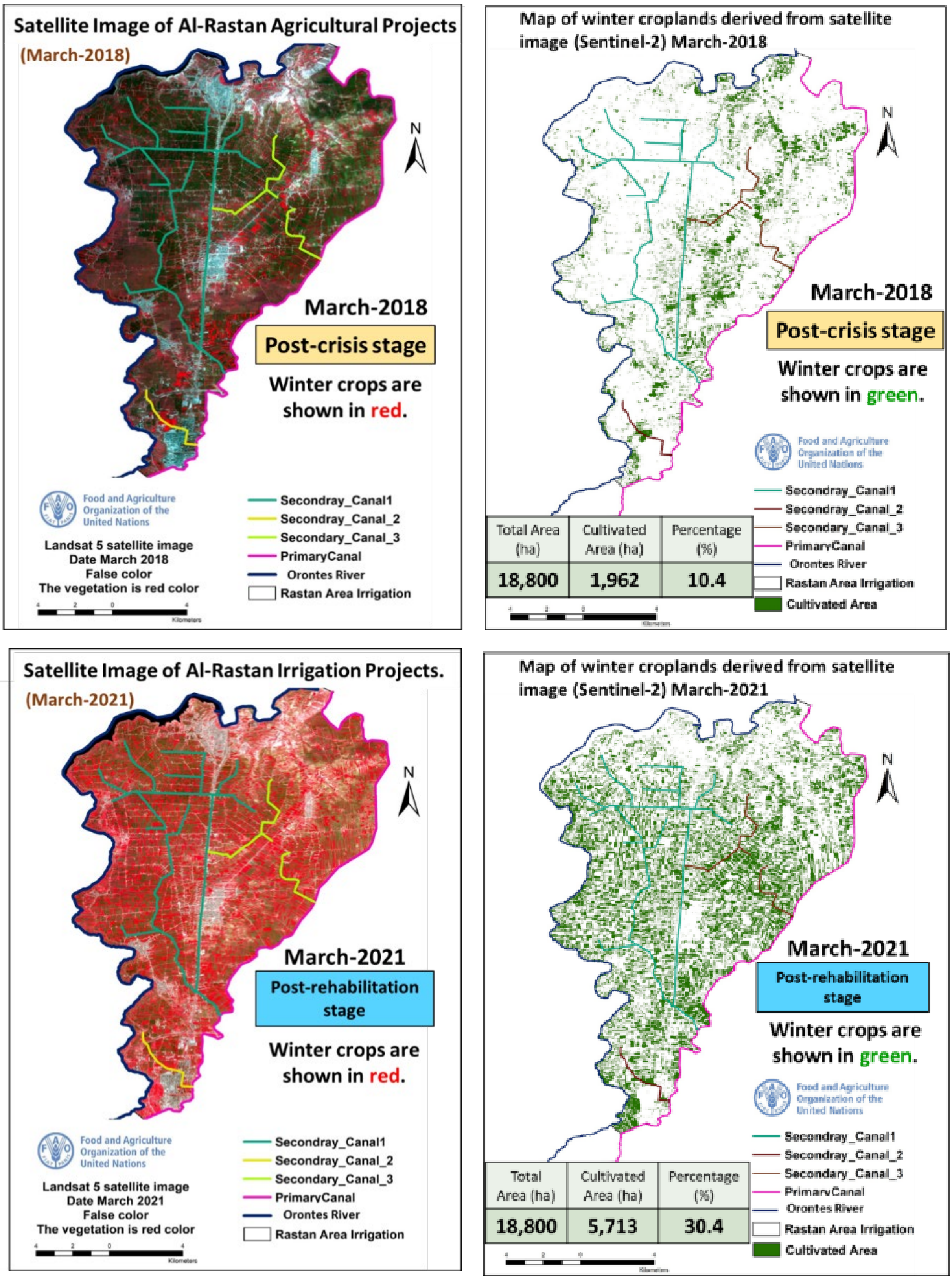


Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network, remote sensing data (Sentinel-2).

Change in the area planted with winter crops (with supplemental irrigation)

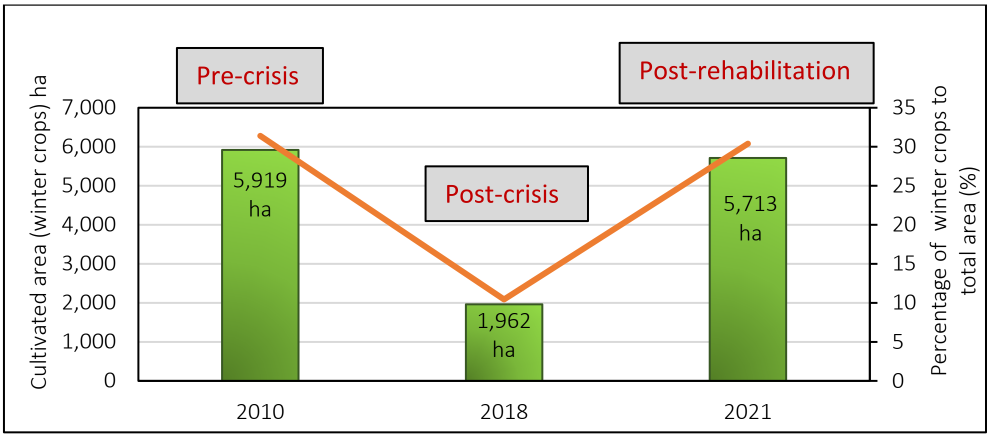
Winter crops are usually rainfed in Al-Rastan region, and their growth depends on the rainfall that usually falls during from November to March (sometimes to April). However, in drought years, due to the early cessation of rain, rainfed crops usually need supplemental irrigation. The years 2018 and 2021 are considered among the driest years in the target area. The winter rainfed crops were in dire need of supplemental irrigation during these two years. In 2018, the irrigation networks were still damaged and there was no possibility of supplemental irrigation, which negatively affected the winter crops represented by a large degradation of their cultivated areas (Figure 24, top maps) and a sharp decrease in their agricultural productivity. On the contrary, in 2021, the rainfed winter crops were able to obtain supplemental irrigation from the irrigation networks that were already rehabilitated, which reflected positively on their cultivated area (Figure 24, lower maps) and their agricultural production. The area of winter crops was estimated using remote sensing data to be about 5 900 ha in 2010 (pre-crisis). This area decreased drastically in 2018 (post-crisis) and reached about 1 960 ha, as shown in Figure 25. In 2021, the area increased significantly until it reached about 5 700 ha.

Figure 24. Winter crops for the year 2018 (post-crisis, pre-rehabilitation) and the year 2021 (irrigation networks rehabilitated)



Source: Adapted from Landsat 5 and Sentinel-2 satellite imagery modified by the authors.
Note: Supplemental irrigation contributed beneficially to the production of winter (rainfed) crops in 2021.

Figure 25. Change in cultivated area (winter crops) over the period from 2010 (pre-crisis) through 2018 (post-crisis, damaged irrigation networks), till 2021 (post-rehabilitation)



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network, remote sensing data (Landsat 5).

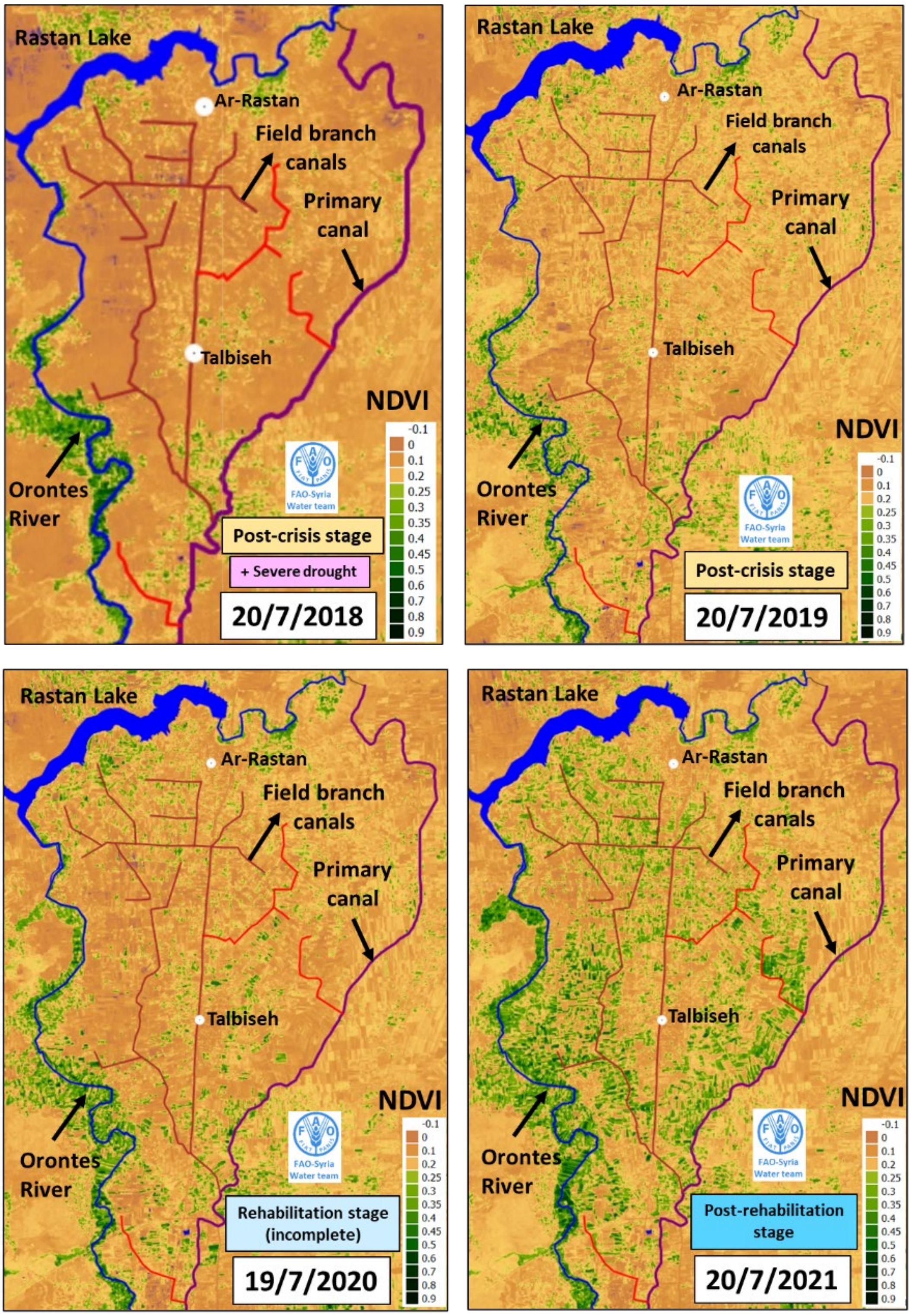
Normalized Difference Vegetation Index

Vegetation indices derived from remote sensing data are quite simple and effective algorithms for quantitative and qualitative evaluations of vegetation cover, vigour, and growth dynamics. One of the most used and implemented indices calculated from multispectral information as normalized ratio between the red and near infrared bands is the NDVI. This index can be correlated to a wide variety of vegetation parameters, including biomass, photosynthetic activity, extent of green cover and productivity.

NDVI values range between -1.0 and +1.0, where increasing positive values indicate increasing green vegetation and negative values represent surfaces free of vegetation such as water and bare soil. In more detail, negative values of NDVI (values close to -1) correspond to water. Values close to zero (-0.1 to 0.1) generally correspond to arid regions of rock, sand or snow. Low and positive values represent shrubs and grasslands (approximately 0.2 to 0.4), a positive value (0.4 to 0.8) for irrigated crops, while high values (values close to 1) indicate temperate and tropical rainforests. With the help of Google Earth Engine platform, four NDVI images were produced using high-resolution satellite images (Sentinel-2 / 10-metre resolution) to monitor and investigate the changes in vegetation cover (summer crops) in the target area (Al-Rasten region) during the last four years (2018–2021), see Figure 26. The acquisition date of the satellite images used for producing the NDVI maps was selected to be during the second dekad of July of each year, which coincides with the period in which the summer irrigated crops have the highest values of NDVI.

By comparing the vegetation cover (irrigated summer crops) shown in green colour on the NDVI maps, it turns out that the area of irrigated crops was minimal in 2018 due to damage to irrigation networks. The cultivated area witnessed a slight increase during the summer months of the years 2019 and 2020, while the increase was very noticeable during the year 2021 (as a result of the completion of the rehabilitation of irrigation networks and the application of irrigation). It is noted that the results of the impact assessment using the NDVI index are in full agreement with those derived from the classification of the satellite images mentioned above.

Figure 26. NDVI maps July of the last four years (2018–2021)



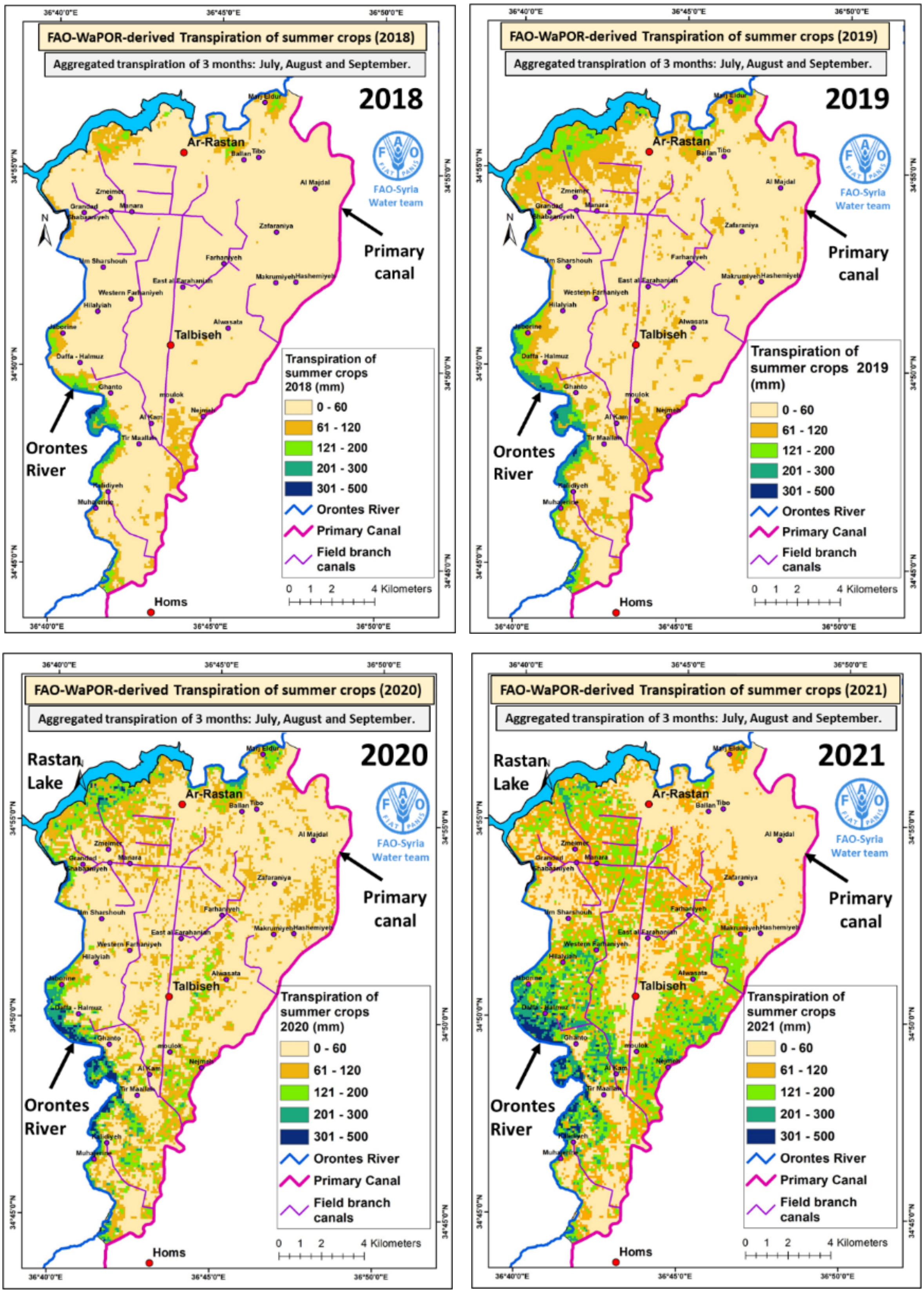
Source: Adapted from Google Earth Engine platform modified by the authors with remote sensing data (Sentinel-2).
Note: It is obvious that the NDVI values in the year 2021 are the greatest, and this is due to the rehabilitation of irrigation networks.

Change in the net primary production (using FAO-WaPOR)

The net primary production can be used to indirectly provide useful information about the biomass production in Al-Rastan region during a specific period of time (dekad or month). According to FAO-WaPOR documentation, net primary production is a fundamental characteristic of an ecosystem, expressing the conversion of carbon dioxide into biomass driven by photosynthesis. It is measured in grammes of carbon per square metre (gC/m^2). The accumulation in biomass production over a growing season is derived, first through the identification of the start and the end of the growing season. Total biomass production is then calculated as the sum of net primary production in gC/m2 unit, converted into dry matter productivity units (kg/ha), between the start of the season and the end of the season.

Four net primary production maps were produced to give a general picture through which biomass production (summer crop production during August) can be compared between the years 2018 to 2021. As can be seen from these maps, in August 2021, most of the croplands in Al-Rastan region have benefited from the rehabilitation of irrigation networks and were well watered, which has led to an increase in their agricultural production (biomass productivity). The impact assessment results obtained using the net primary production are also consistent with the previously mentioned results, see Figure 27 and Figure 28).

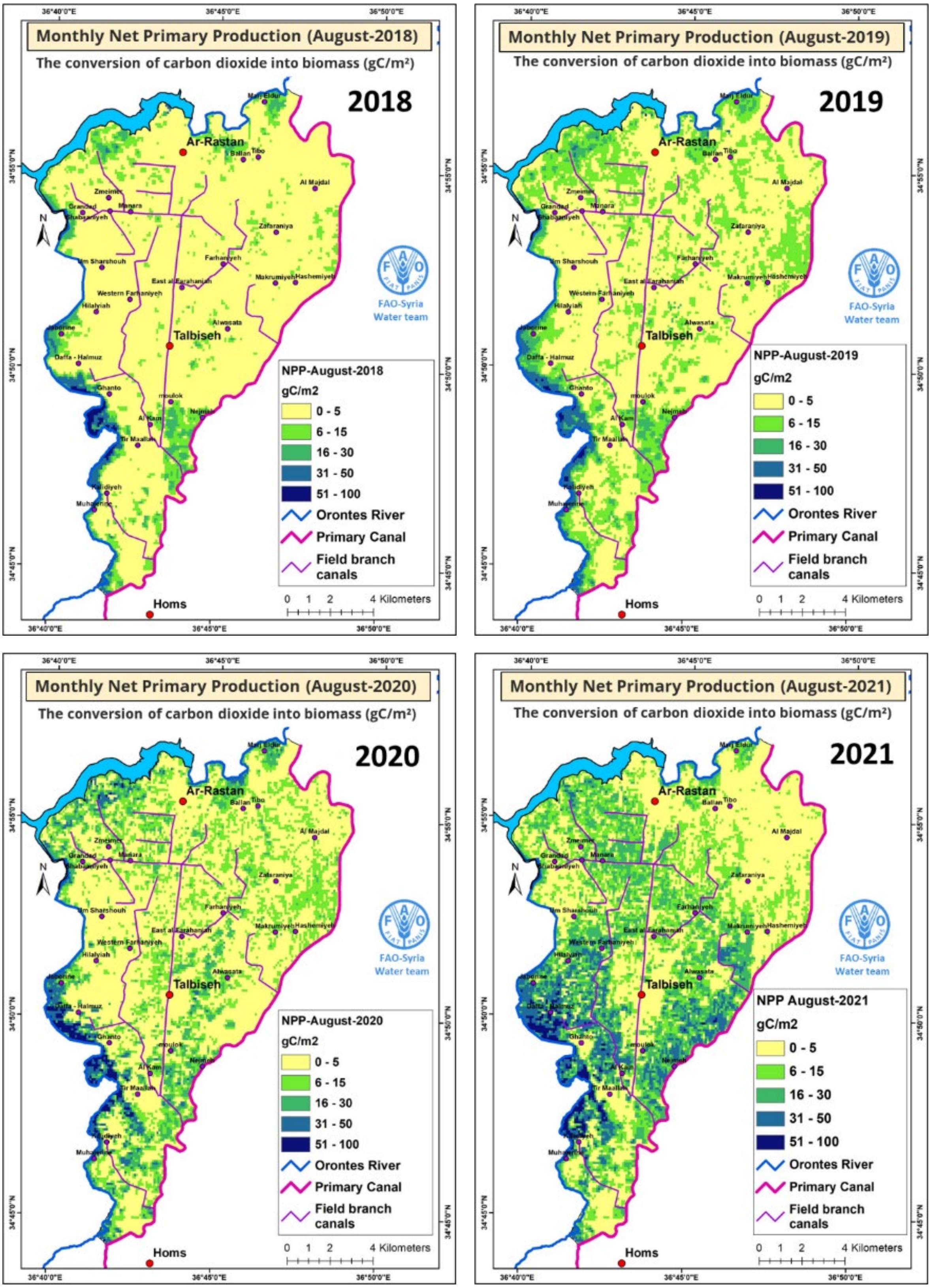
Figure 27. Transpiration of summer crops (aggregated for the months of July, August and September) 2018 to 2021



Source: Adapted from WaPOR modified by the authors.

Note: Transpiration in the hot, rainless summer months can be viewed as an indicator of the amount of irrigation app.

Figure 28. Net primary production in August, expressing the conversion of carbon dioxide into biomass (gC/m2) driven by photosynthesis, 2018–2021



Source: Adapted from WaPOR modified by the authors.

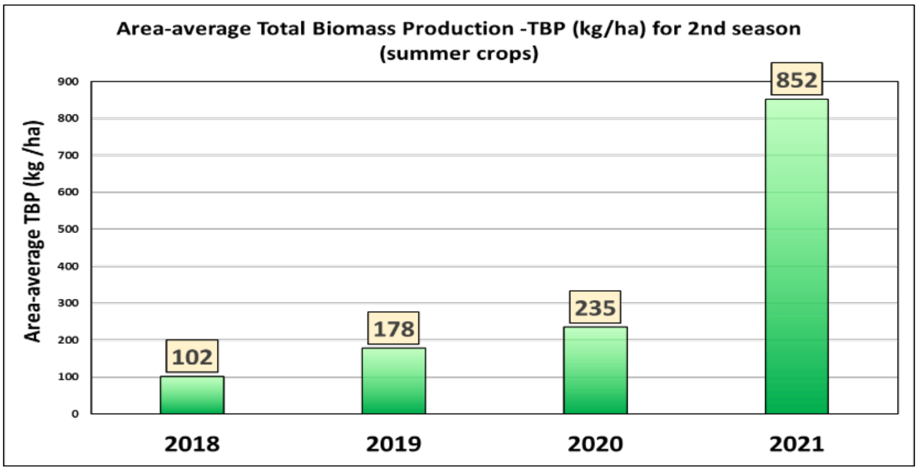
Note: Net primary production can be converted from gC/m2 into total biomass production (kg/ha) by applying a unit conversion factor. July 2021 shows the highest values of net primary production as a result of the rehabilitation of the irrigation network and the irrigation of crops.

Total biomass production (kg/ha)

As mentioned in the paragraph of net primary production, total biomass production is calculated as the sum of net primary production in gC/m2 unit, converted into dry matter productivity units (kg/ha), between the start of the season and the end of the season. Unlike net, which is available on a dekadal or monthly basis, total biomass production is only available on a seasonal (winter and summer seasons) or annual basis. However, as the focus is on assessing the impact of rehabilitation of irrigation networks on agricultural production, four total biomass production maps have been produced for the second season of each year during which irrigated summer crops are usually planted, see Figure 30.

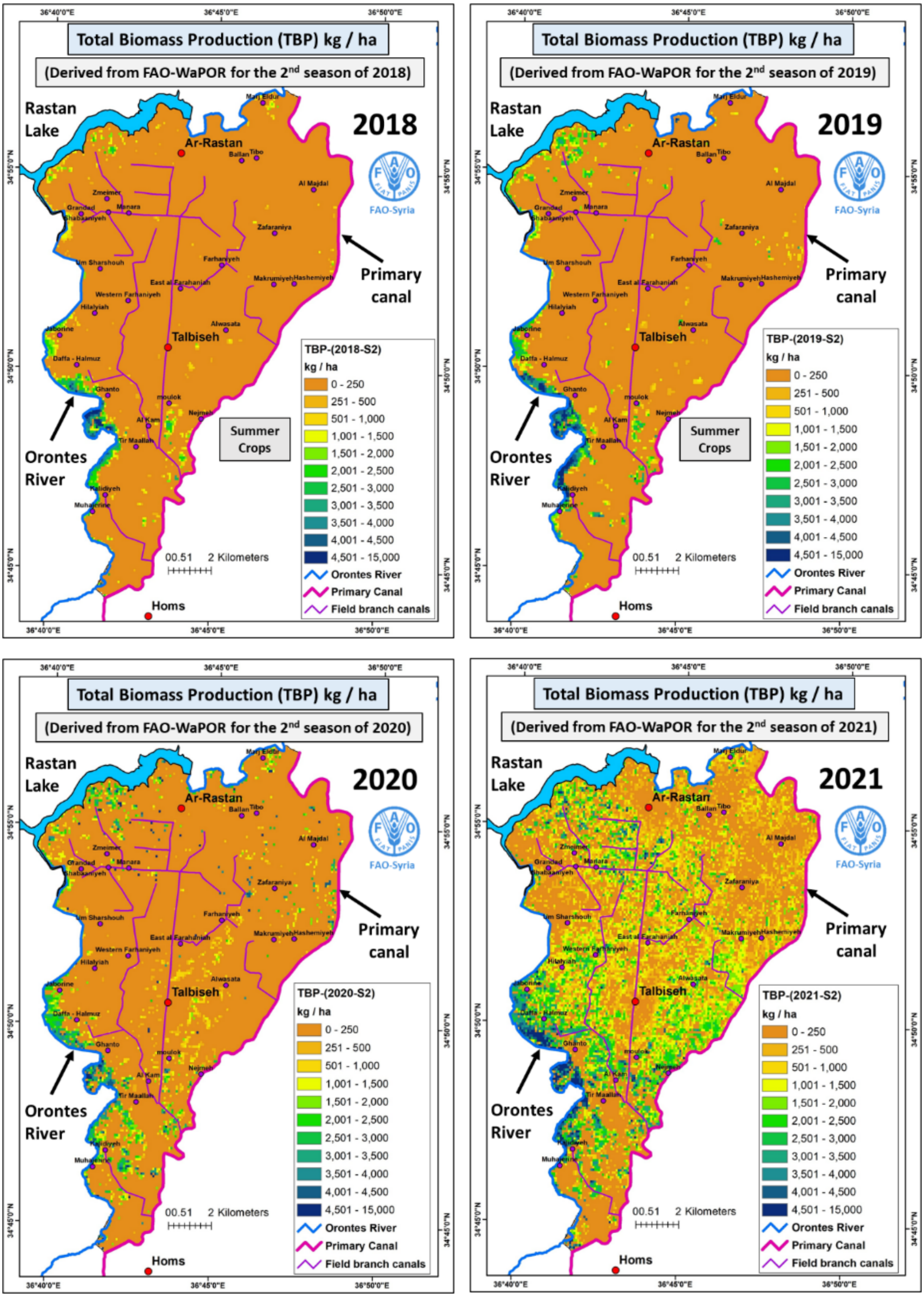
It is clear from these maps, as well as from the chart of the variation in the area-average value of total biomass production (Figure 29), that the year 2021 witnessed a significant increase in total biomass production compared to the previous years as a result of the rehabilitation of the damaged irrigation networks.

Figure 29. Change in the area-average total biomass production (kg/ha) for the second season (summer crops), 2018–2021



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network, remote sensing data (WaPOR).

Figure 30. Total biomass production (second season) 2018–2021

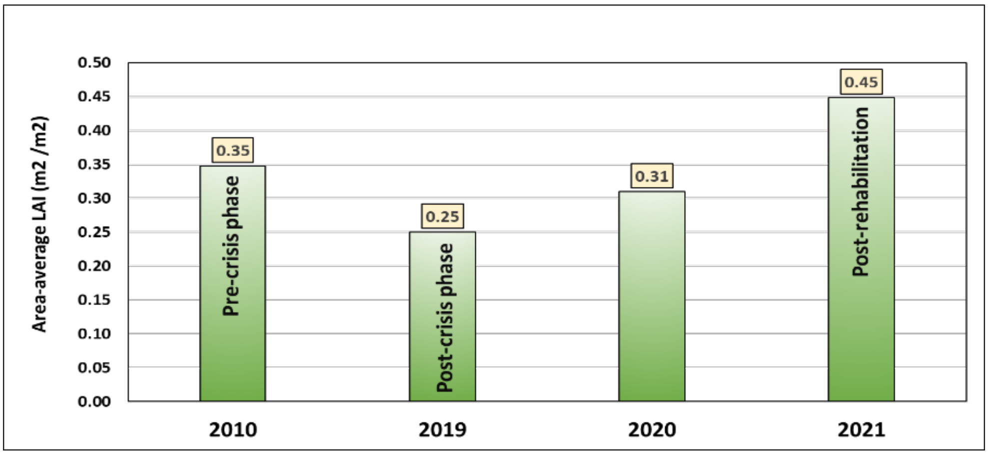


Source: Adapted from WaPOR modified by the authors.

Leaf area index

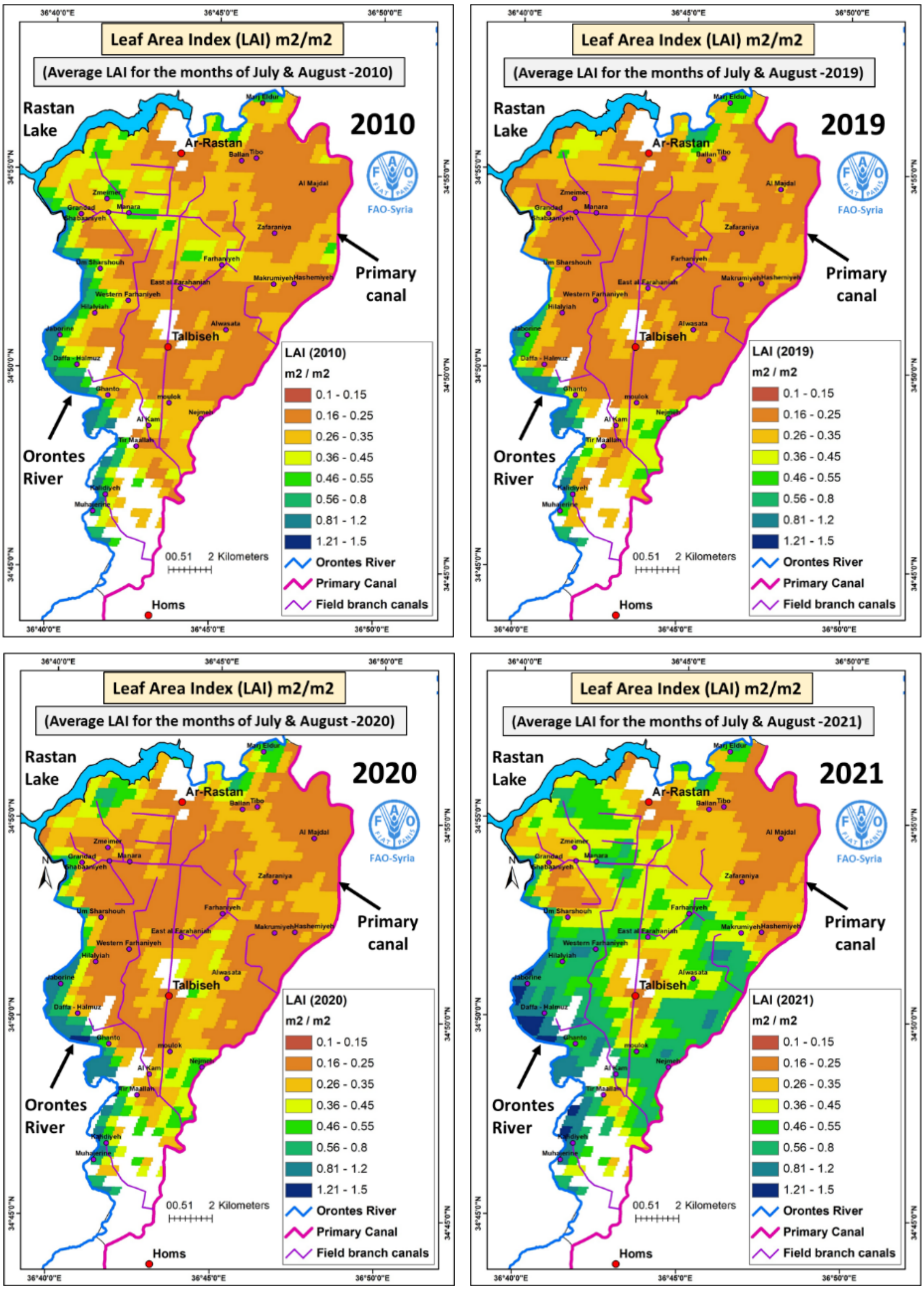
Leaf area index is calculated as half the area of all plant leaves per unit area of ground. It is measured as the leaf area (m^2) per ground area (m^2) and is unit-less. So, a plant with a leaf area index of 2 has a number of leaves that can cover a given area two times. Since leaves are important for photosynthesis and produce the bulk of biomass, the number of leaves (and leaf area index) will also influence crop yield. Comparisons of leaf area index between different years is a good approach to judge how well the crops are doing. Four leaf area index maps (Figure 32) were produced as average leaf area index of two summer months (July and August) to assess the impact of the rehabilitation of the irrigation network on the vegetation cover in the target area. As illustrated on these maps, as well as in the Figure 31, the leaf area index values increased in the summer months of 2021 as a result of the rehabilitation of the irrigation network.

Figure 31. Variation in the average leaf area index for the months of July and August of the years 2010, 2019, 2020 and 2021



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study, remote sensing data (MODIS).

Figure 32. Average leaf area index (July and August) for the years 2010, 2019, 2020 and 2021



Source: Derived from MODIS using Google Earth Engine modified by the authors.

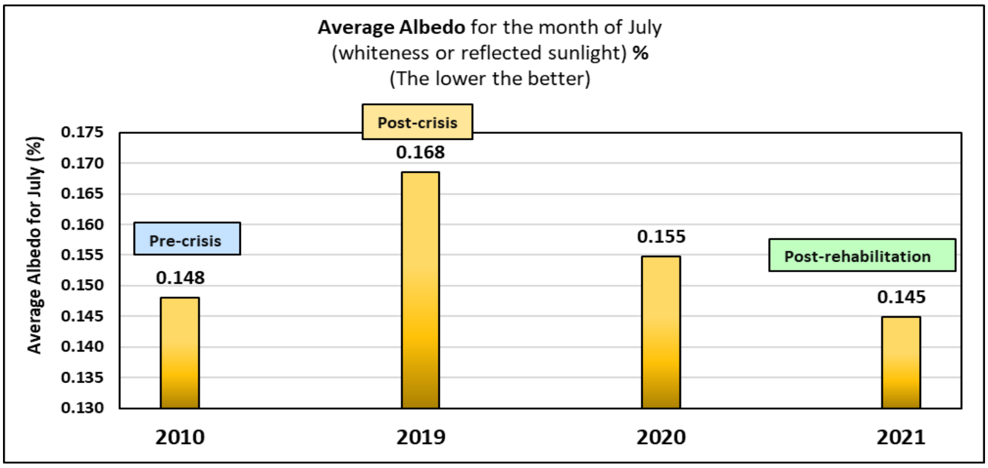
Impact on soil health/land degradation

Albedo (whiteness or reflected sunlight)

Albedo is a measure of the proportion of incident light or radiation that is reflected by a surface. It is a spectral property of the earth's surface that can be estimated from remotely sensed data. The change in albedo can be used as an indicator of soil (or land) quality, which takes care of both physical and biological behaviour of the land surface characteristics depending on its land cover. Considering same atmospheric and solar conditions for the two sets of remote sensing data acquired at different dates (before and after the rehabilitation) of same geographical area, the temporal change of albedo can be assessed and correlated with land degradation or land improvement. Land degradation (or even desertification) can be manifested by reduced soil moisture, decreased vegetation density, decreased organic matter, or increased erosion. An increase in organic matter in the soil leads to a darker colour of the soil, which leads to a decrease in albedo. In general, and especially in arid and semi-arid regions, it can be said that increases in albedo indicate land degradation and decreases indicate improvement of land.

A long-term series of remote-sensing derived albedo for Al-Rastan region were collected and analysed using Google Earth Engine. A comparison between the albedo values recorded in the target area before and after the rehabilitation of the irrigation projects revealed the impact of this project on improving soil quality and reducing desertification, see Figure 33 and Figure 34. A smaller albedo value indicates healthy land.

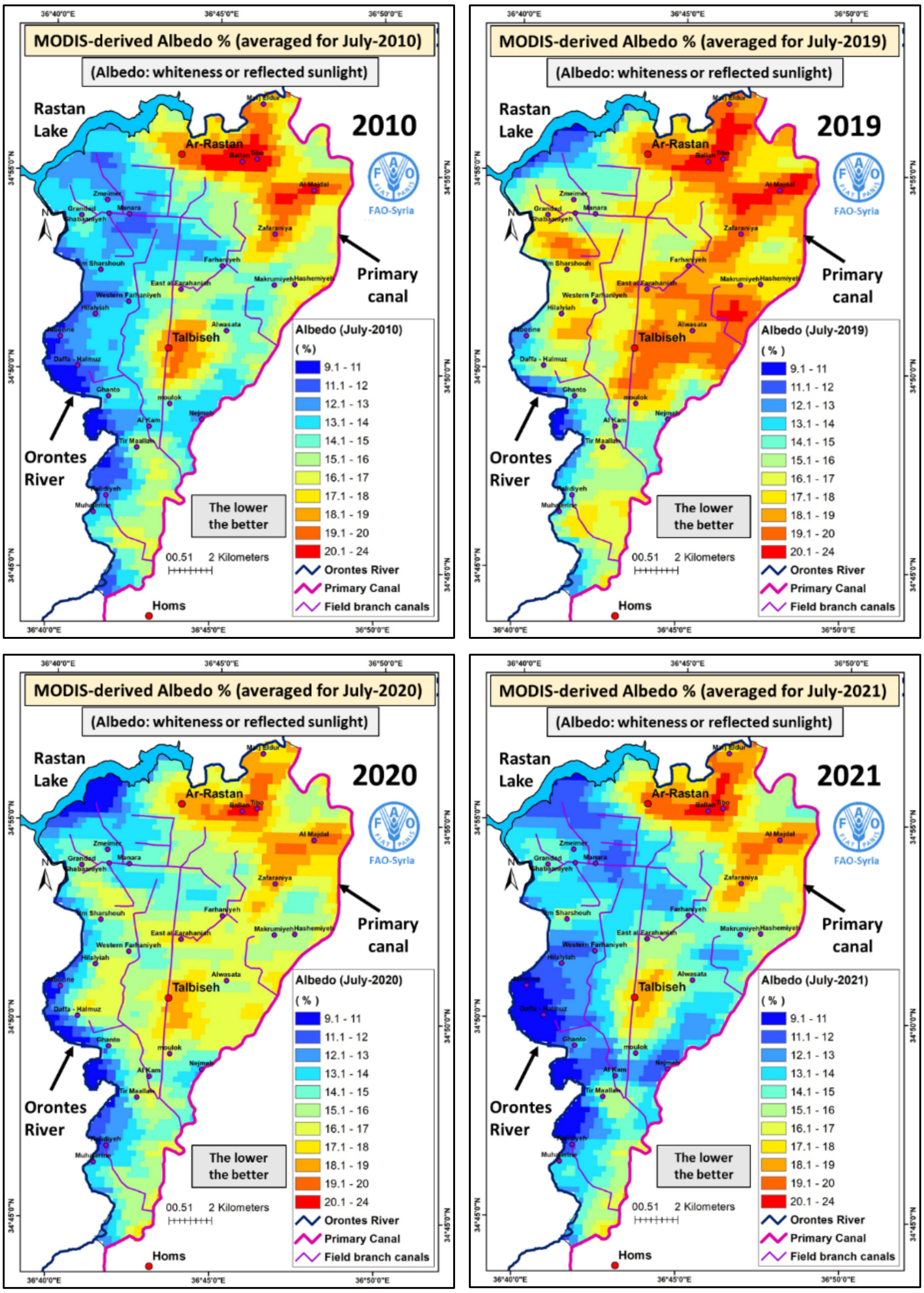
Figure 33. Variation in the average albedo (for the month of July) of the years 2010, 2019, 2020 and 2021



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study, remote sensing data (MODIS).

Note: The lower the albedo value, the healthier the soil.

Figure 34. Albedo maps (averaged for July) for the years 2010, 2019, 2020 and 2021



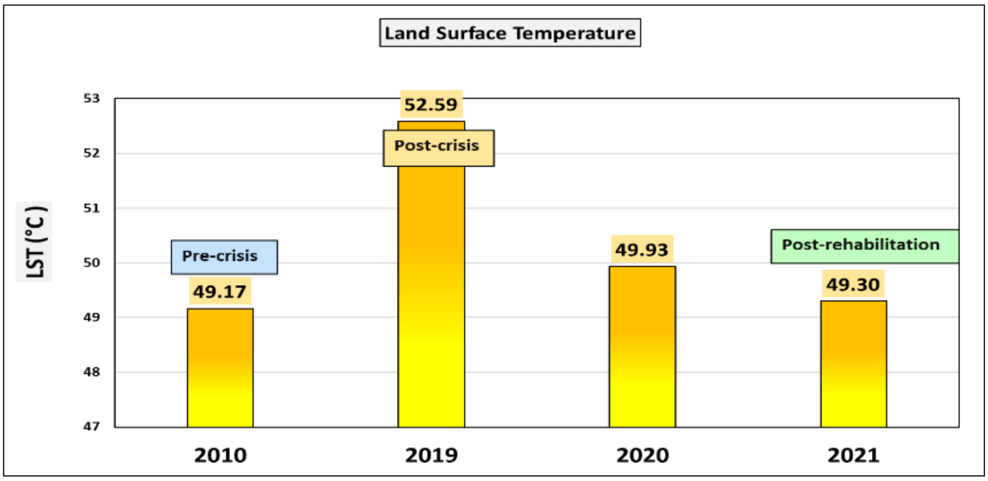
Source: Derived from MODIS using Google Earth Engine modified by the authors.

Land surface temperature

Land surface temperature is an important parameter related to surface energy and water balance of any given area. It is considered as an essential aspect of climate and biology, affecting organisms and ecosystems from local to global scales. Land surface temperature can be used as indicator of surface-moisture status, and thus for monitoring drought and plant stress in agricultural and natural ecosystems. Irrigation activities can lead to a significant colling at the land surface temperature as well as in the 2-m air temperature, but to a lesser extent. This colling occurs because solar energy arriving on an irrigated field evaporates the water rather than heating up the land surface (and thus the air above the land). Comparing the remote-sensing derived land surface temperature of the summer irrigated areas before and after the rehabilitation of irrigation networks revealed good information about the evaporative cooling effect of the irrigation (transpiration cooling). It is well known that drought stress triggers stomatal closure, which in turn limits the plant ability to avoid the warming stress through transpiration cooling. Thus, drought together with warming and soil dryness, may significantly limit the growth and survival of plants.

Figure 36 shows the produced land surface temperature maps (as average for the month of August) as derived from LANDSAT-images using Google Earth Engine for the years 2010, 2019, 2020 and 2021. As can be seen from these maps, as well as from Figure 35, the irrigation operations applied in August 2021 (after rehabilitation) led to a decrease in the land surface temperature, which is seen an indicator of soil health.

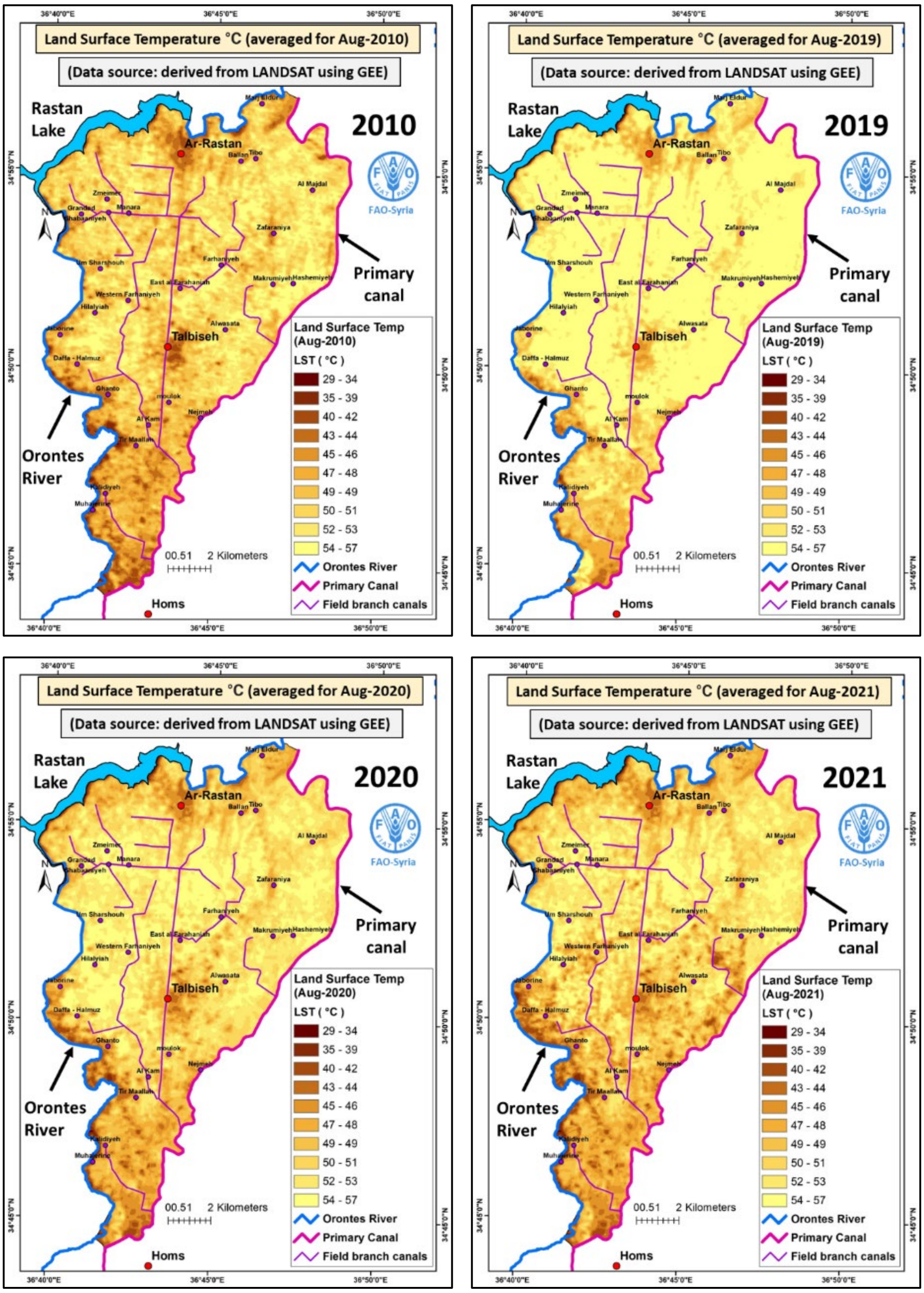
Figure 35. Change in the area-average land surface temperature (for the month of August) of the years 2010, 2019, 2020 and 2021



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study, remote sensing data (LANDSAT).

Note: The lower the average land surface temperature value, the healthier the soil.

Figure 36. Land-surface-temperature maps (averaged for August) for the years 2010, 2019, 2020 and 2021

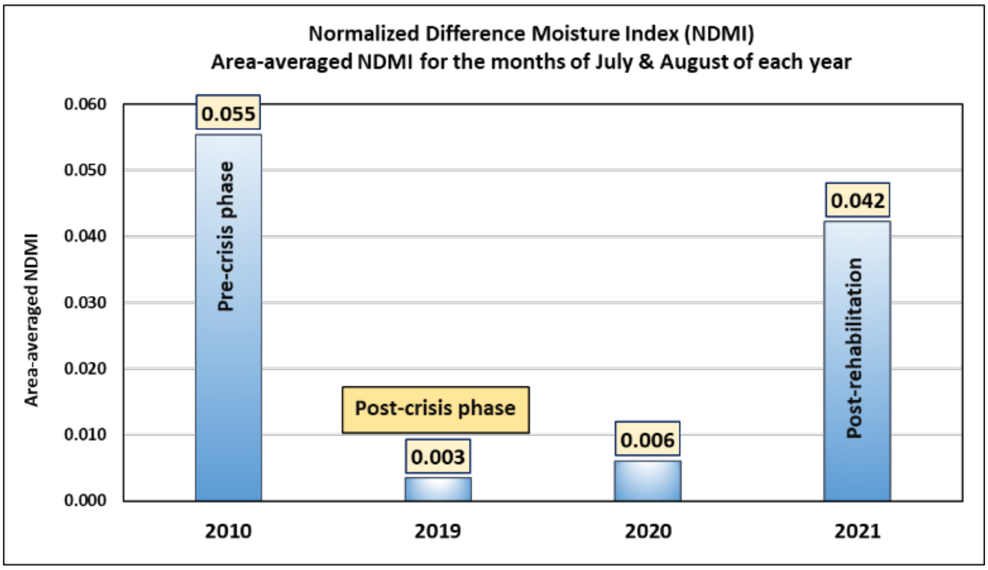


Source: Derived from LANDSAT images using Google Earth Engine modified by the authors.

Normalized Difference Moisture Index

Soil moisture can be considered as a measure of soil health, however, since measurements of soil moisture available from remote sensing techniques are still relatively coarse (the spatial resolution is not suitable for estimating soil moisture in the target area), it was preferable to use the NDMI as an indirect indicator of soil moisture from which plants absorb their water requirements. NDMI is used to determine moisture levels in vegetation using a combination of near-infrared and short-wave infrared spectral bands. It is a reliable indicator of water stress in crops. NDMI have values between -1 and +1. The lowest values (the blue colour on the maps shown in Figure 38) indicate low vegetation water content, and the highest ones (in red) correspond to high water content. In other words, decrease in NDMI will indicate water stress, while abnormally high NDMI values could signal waterlogging. It is obvious from these maps, as well as from Figure 37, that the area-average NDMI significantly increased in the summer months (July and August) of the year 2021 (after rehabilitation) indicating an increase in the average soil moisture and thus an improvement in its health.

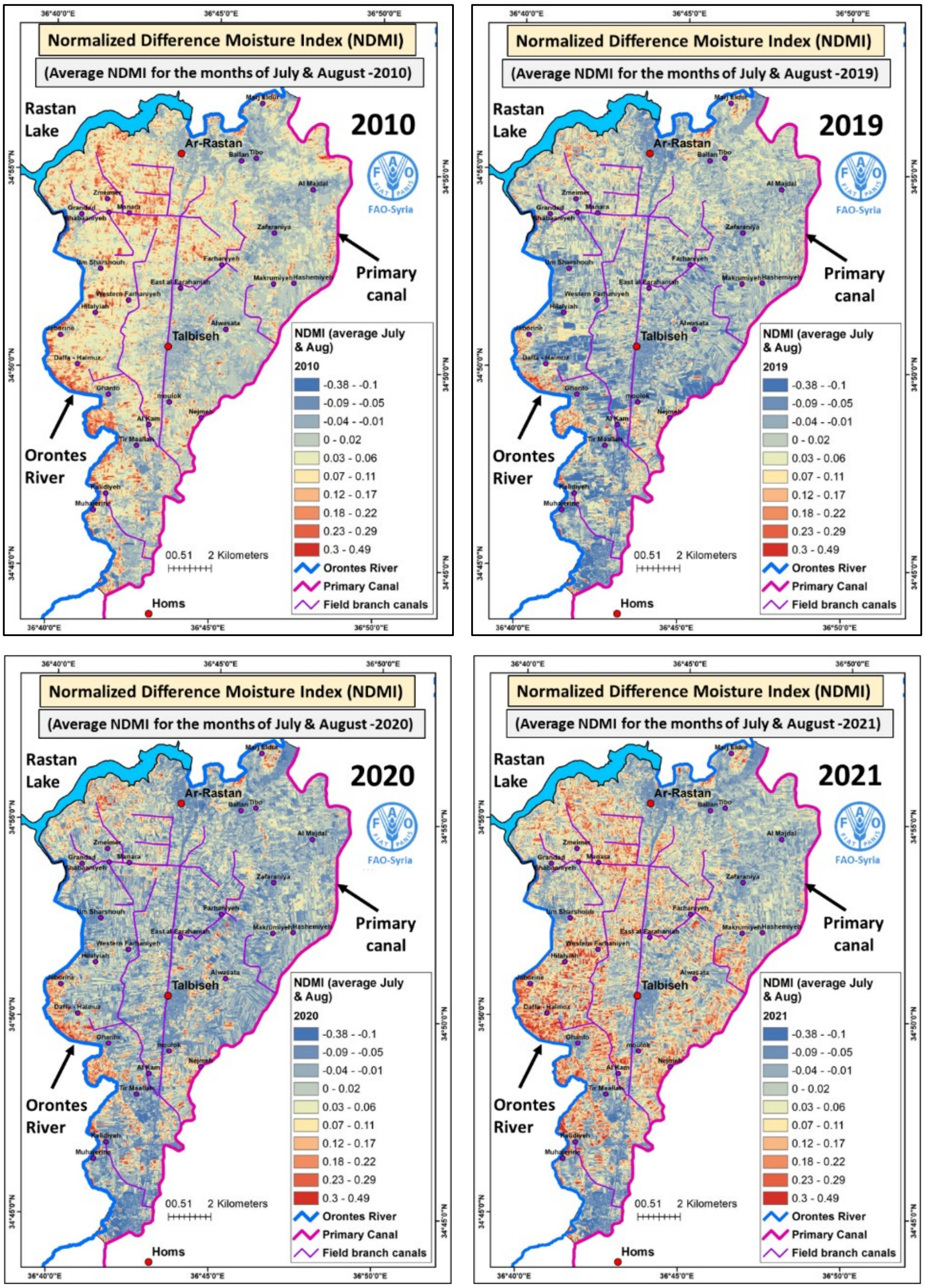
Figure 37. Variation in the area-average NDMI (July and August) of the years 2010, 2019, 2020 and 2021



Source: FAO. 2022. Capitalization of the rehabilitation of Al-Rastan irrigation network study, remote sensing data (Sentinel-2).

Note: The higher the average NDMI value, the healthier the soil.

Figure 38. NDMI maps (averaged for the months of July and August) for the years 2010, 2019, 2020 and 2021



Source: Derived from Sentinel-2 images using Google Earth Engine modified by the authors.

Conclusion

Based on the multidimensional capitalization study for the rehabilitation of the Al-Rastan irrigation network and its impact, the following can be concluded:

- The main objective of the rehabilitation intervention has been met and the assigned activities have been implemented as planned to open access to water for irrigation through Qattina Lake, reducing water losses through evaporation. It resulted in the following achievements:
  - twenty-nine local irrigation structures rehabilitated along the primary irrigation canal;
  - maintenance works for the concrete lined on-farm irrigation network and related groundwork completed (the implemented work is related to field branch canal number 1, 2 and 3 where about 64 irrigation structures were rehabilitated, 8 000 m^3 of concreted were casted and 12 km of concrete lined canals were restored);
  - field branch canals 1, 2 and 3 (60 km length), tertiary canals (20 km) and Ghneih Al-Assi Roman irrigation canal (8 km) rehabilitated;
  - five irrigation management centres rehabilitated and six WUAs established;
  - irrigation management capacity enhanced for 40 trainers and 800 farmers;
  - access to irrigation water opened for 31 villages:
    - direct: 20 villages within the Al-Rastan irrigated area, 11 000 ha benefiting about 20 000 households; and
    - indirect: 11 villages in Hama irrigated area (downstream locations), 7 500 ha benefiting 10 000 households.
- Access to irrigation water contributed to increased cultivated areas. Summer cultivated areas increased from about 687 ha in 2018 to about 5 180 ha in 2021 (about 28 percent of the total area) while winter cultivated crops increased from 1 962 ha in 2018 to 5 713 ha in 2021 almost as same as it used to be in 2010. During the field study, visited farmers in the targeted villages confirmed an increase in crop areas between 2020 and 2021, they reported that summer crops area increased from 808 to 1 539 ha, other crops cultivated areas increased from 547 to 1 754 ha, and winter crops area from 6 406 to 8 470 ha.
- Production of different crops has also increased significantly for all crops, and it was estimated at 67 percent for wheat, 178 percent for onion, 756 percent for yellow corn (maize) and 122 percent for sunflower. Further, access to irrigation water has improved diversification of agriculture i.e. change in cropping pattern to include a wider range of summer crops and other crops (in between summer and winter seasons), which were very limited before rehabilitation.

- Remote sensing analyses confirmed the results on increased cultivated areas through NDVI, leaf area index, total biomass production and net primary production. Cultivated areas for summer crops increased from 16.6 percent to 27.6 percent of the total study areaand from 10.4 percent to 30.4 percent of the total study area for winter crops.[6] The results obtained from the remote sensing data analysis correspond to the results of the collected data and information from the field.
- The investment of the irrigation network after rehabilitation contributed to the increase in livestock activities benefiting from crop residues and as a result of more cultivated area with feed crops. It was estimated at the sample level that the numbers of cattle, sheep, goats, and poultry have increased by 22 percent, 29 percent, 25 percent and 31 percent respectively. On the other hand, the constantly rising prices of feed, vaccines and veterinary treatment still poses a serious challenge for livestock breeders.
- The improved situation of agriculture in terms of production and diversification had a significant effect on the socioeconomic status of the beneficiaries in the study area. This was reflected in improved income and food security (based on FCS) as the poor and borderline groups declined by 4 and 7 percent respectively while the acceptable FCS group food increased by 11 percent. Further, improved situation after resuming the main source of livelihoods was evident in the number of returnees to the study area after rehabilitation and which was estimated at 4 108 households.
- On-ground measurements and laboratory tests revealed that the groundwater level has increased by an average of 2.014 metres. The water quality analysis revealed that the rehabilitation had no adverse effects on groundwater quality, and it was found suitable for domestic use (within the standards of potable water).
- The analysis of the surface water revealed that the agricultural activities and inputs had no adverse effects on surface water quality, and it was found suitable for irrigation purposes.
- Remote sensing analyses in terms of environmental impacts indicated improved quality of soil, reduced degradation (decreased albedo index and land surface temperature), increased moisture content (NDMI) and lower risks of water stress and clogging compared to the pre-rehabilitation period.
- The experience of WUAs is moving forward with current 6 six WUAs covering 1 523 ha and 16 new WUAs being established to cover 4 475 ha of the study area. The results of the study sample revealed that 91 percent of farmers received irrigation water as per schedules (an indication of the good performance of the established WUAs). As perceived by the local community, the performance of WUAs is improving in achieving irrigation management at the farm level and in taking a role in water governance at all levels. The local

[6] The irrigated area is 11 000 ha within a total study area of 18 800 ha.

communities are more accepting of the concept of WUAs than before, and they showed more willingness to be involved in the activities of the WUAs. This is crucial for the sustainability of the irrigation system, the water resources and livelihoods.

- The participation of women in different activities was encouraged throughout the intervention activities. It was very evident in the capacity building programme with 34 percent of female trainers and 52.8 percent female trained farmers. The participation of women in WUAs was only limited due to land ownership issues. However, it has taken a step forward through facilitating women's participation especially if they are the main provider for their household. During the field missions and interviews with the local communities, women were also encouraged to participate in the discussions (almost 25 percent of the met farmers) and to take an active role in WUAs. It is, therefore, expected that representation of women will be more evident in the foreseeable future, especially in the new WUAs.

Recommendations

- To maximize the benefits of the intervention, and enhance irrigation management at farm level, performance of the WUAs should be monitored and supported. This could be through further training, raising awareness and technical support especially regarding operation and maintenance. Furthermore, the promotion of the participatory irrigation and enhancing farmers' sense of ownership could in turn enhance their cooperation within the WUA. This has a longer-term benefit in terms of handling more extensive and complex responsibilities on larger areas.
- To enhance water use efficiency and address water scarcity issues within the prevailing climate change circumstances, the application of modern and efficient irrigation techniques and climate smart agriculture practices could be further explored to be implemented in the target area where applicable.
- A step forward has been taken regarding women's participation in the WUAs as irrigators and food producers. However, the role of women should be further strengthened through specialized activities that build their capacity, empower them, and enhance their confidence to participate in management and decision-making processes.
- A comprehensive study of the marketing channels, challenges and opportunities is needed to maximize the benefits of agricultural production for farmers. Access to inputs can add to the benefit of improved access to water to develop the agricultural value chain. It is also important to consider improving access to post-production value infrastructure such as cooling, storing and packaging facilities.
- Enhancing the capacity of irrigation and agriculture extension units could be of great assistance to farmers. This may include the provision of advisory services related to irrigation techniques and practices, identify best seeds and fertilizers, marketing channels and market price. It is thought that by activating this role, farmers would be able to practice more productive and profitable agriculture while reducing losses due to lack of awareness and exploitation of traders.
- The capitalization study is a good approach to assess the impact of the activities implemented using advanced technology with compatible indicators. It reflects multidimensional impacts and paves the way for further improvement of the farmers' livelihoods using available natural resources in a sustainable way.

References

Central Bank of Syria. 2022. Exchange rate. In: *Central Bank of Syria.* Damascus. [Cited 15 January 2022]. www.cb.gov.sy

Central Bureau of Statistics. 2022. Statistics. In: *Central Bureau of Statistics.* [Cited 15 January 2022]. www.cbssyr.sy

Crawford, I.M. 1997. *Agricultural and food marketing management.* Rome. FAO. www.fao.org/3/w3240e/W3240E00.htm

OCHA (Office for the Coordination of Humanitarian Affairs). 2022. *Humanitarian Needs Overview: Syrian Arab Republic.* Geneva, Switzerland. www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/hno_2022_rev-1.15.pdf

Corrigendum – 12.07.2023

The cover and disclaimer page of this publication were updated with the addition of the European Union logo and accompanying disclaimer, to acknowledge the European Union's financial contribution.

Saving livelihoods saves lives

Contact

FAO Representation in the Syrian Arab Republic

FAO-SY@fao.org
fao.org/syria | @FAOSyria
Damascus, Syrian Arab Republic

Office of Emergencies and Resilience

OER-Director@fao.org
fao.org/emergencies | @FAOEmergencies
Rome, Italy

Food and Agriculture Organization of the United Nations

ISBN 978-92-5-137972-1

9 789251 379721

CC6741EN/1/07 23