Regenerative farming and digital tools for salinity control in Egypt, Iraq, and Jordan

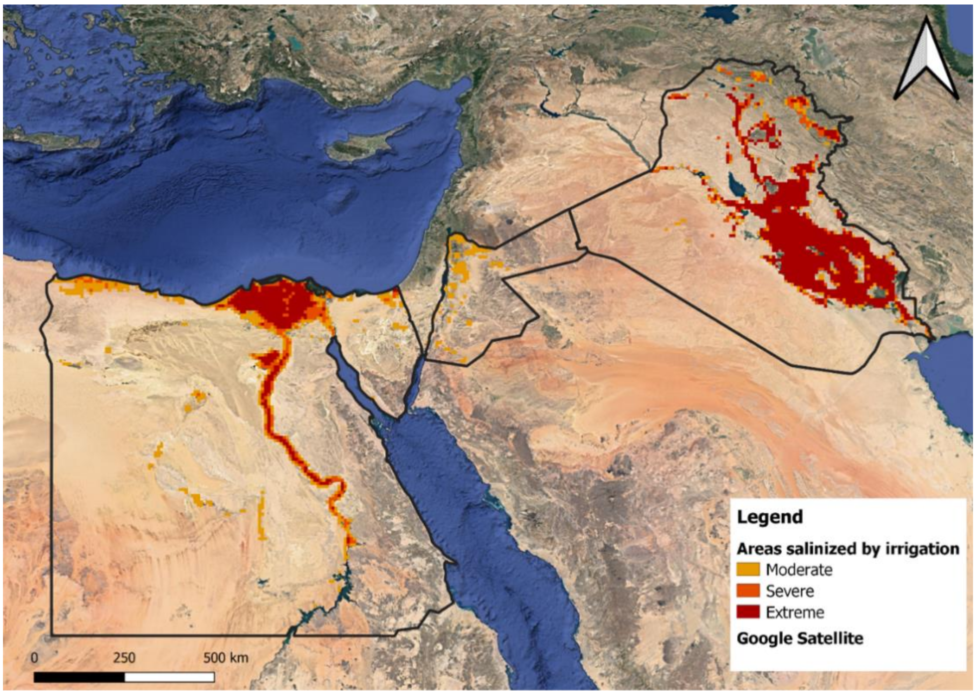
FRAMEWORK TO MAP AND PREDICT SALINITY CONTROL WITH REGENERATIVE AGRICULTURE SOLUTIONS

Report

July 6th, 2023

Client: Netherlands Food Partnership

Netherlands Water Partnership



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Management Summary

Salinization of water and soil resources is a growing problem worldwide that impairs livelihood, food security and socioeconomic development. Against this context the Ministry of Agriculture, Nature and Food Quality, Netherlands Food Partnership (NFP) and Netherlands Water Partnership (NWP) established the so-called 'Saline Water & Food Systems' (SW&FS) partnership platform. The overall goal of the partnership is to strengthen the cooperation of the Dutch SW&FS sector in the international context.

Dutch organizations Nectaerra (lead), FarmTree and WUR conducted a study to assess how several regenerative agriculture practices would help control and mitigate salinity, and how a digital decision support tool called the FarmTree Tool (FTT) could assist in forecasting effects at a farm-level and could help in the design process.

We chose several typical regenerative farming practices that are widely adoptable, in this case the use of cover cropping, mulching, trees and improved seed varieties. Subsequently, for six existing farms in Egypt, Jordan, and Iraq we assessed if the selected regenerative agriculture measures could mitigate the effects of salinity, by collecting field data from those farms where one or more of these regenerative measures were implemented. These farms produce mango, tomato, olive, wheat, barley, and potato. The regenerative practices we selected were included as design options in the FTT, while FTT was also fitted with a new module to assess the effects on salinity called the "Suitability to Salinity", defined as a measure (0-100%) by which a crop can perform its normal physiological functions without being affected by salinity.

The FTT predictions were compared to the field data of the regenerative practices vs. the business-as-usual field data. Several conclusions are drawn; firstly, the regenerative practices did have a positive effect on the crop's ability to sustain production (yield) under saline conditions. Secondly, field validation data and the FTT show similar positive results on crop performance under saline conditions for regenerative practices for all regenerative practices combined. However, we found that FTT did not consistently predict the outcome of individual practices, and we therefore conclude that the applicability to use FTT on a farm level is currently not advisable for semi-arid regions. FTT requires updating with more scientific data and case study data to boost reliability. The effect on water salinity was currently not determined, and more work is needed to relate differences in water consumption between regenerative and business as usual (BAU) practices, to water salinity.

The FTT can provide valuable insights into how the environment, salinity, and water levels may affect new cultivations and the impact this has on farm economics and climate resilience. The FTT is less suited as a design tool at a farm level, but it does offer perspective on the effects of regenerative practices for larger areas if it has been properly calibrated for the area in question and is used by someone experienced in implementing regenerative agriculture practices. FTT currently does not allow cost-benefit analysis in semi-arid regions, nor the effects of other sustainability indices (e.g. soil fertility) under saline conditions. This requires more data and FTT updating.

Intended follow-up of this project involves field data collection on regenerative practices, updating FTT, and making use of any opportunities to develop capacity among potential users and showcase how regenerative agriculture is a solution for salinity problems and FTT can be used in the process. The projected end goal is that regenerative agriculture practices are seen and proven to be the most effective measure to control and mitigate salinity, and that FTT can be used as a validated tool to predict the effect on salinity of those regenerative practices.

List of abbreviations

Abbreviations are used in this text, especially graphs. They are explained below:

Acronym	**Term**	**Explanation**
AFS	Agroforestry system	An arrangement of multi-annual crops and trees, and annual crops; that provides a mix of social, environmental, and economic services
BAU	Business as usual	The land performance simulation of the baseline (without a land restoration activity) scenario (land use option)
CBA	Cost Benefit Analyses	Analyses aimed at assessing the economic feasibility of specific actions/project/policy.
4C	Customized cover and companion crops	Site-specific mixtures of plants that cover the soil and/or support the main crop(s)
DSS	Decision Support Systems	Refer to a broad range of computer-based tools (simulation models, and/or techniques and methods) developed to support decision analysis and participatory processes
FTT	FarmTree® Tool	Digital decision support tool used during the project
RV	Improved Crop Variety (“Resistant Variety”)	Crop variety less susceptible to a specific threat, in this case salinity
WB	Wind Break	Linear planting, in this case composted by trees of different species and characteristics, designed to provide economic, environmental and community benefits

1 Project introduction

1.1 Project background

Salinization of water and soil resources is a growing problem worldwide that impairs livelihood, food security and socioeconomic development. Against this context the Ministry of Agriculture, Nature and Food Quality, Netherlands Food Partnership (NFP) and Netherlands Water Partnership (NWP) established the so-called 'Saline Water & Food Systems' (SW&FS) partnership platform. The overall goal of the partnership is to strengthen the cooperation of the Dutch SW&FS sector in the international context.

Nectaerra, FarmTree and WUR were granted a project to assess the effect of regenerative practices on salinity and the ability of digital tools, in this case the FarmTree® Tool to predict the outcome.

1.2 Regenerative agriculture and digital tools

Conventional agricultural practices – typified by monocropping, anti-biotic management practices and extensive water and artificial input dependency – contribute significantly to rising salinity of soils and water resources worldwide. A new farming approach is required to revert this trend. There is the need for a long-term vision, with a sustainable approach based on practices which will also sustain the farmer on the short-term.

Regenerative agriculture and water management can certainly be part of that solution. Regenerative farming focuses primarily on soil health as the driver for crop yield and quality and helps guarantee a sustainable future where farming is still possible in countries like Egypt, Jordan, and Iraq. Regenerative practices should be adopted to limit the amount of water and artificial inputs, to increase crop resilience to salinity, and to improve livelihoods.

However, farmers are typically hesitant to adopt new practices unless effects, risks and benefits are clear and cashflow remains positive. Adoption of new practices often needs practical demonstration. This approach can be augmented using digital agricultural and predictive ICT tools.

The business proposition is based on the concept of regenerative practices combined with FTT; adopting a joint system based on regenerative farming interventions can reduce salinity, improve performance and yield, and the validated decision support model can predict the effects on salinity in advance.

1.3 Project objectives and research questions

The proposal aims to inventory and categorize typical (saline) farming systems and business models in Egypt, Iraq, and Jordan where salinity onset and effects can be mitigated by a series of sustainable practices and its outcome can be predicted using digital tools, in this case the FTT. These tools allow Cost Benefit Analyses (CBA) of farming systems and to predict effects on sustainability indices such as soil fertility, erosion resistance, carbon sequestration, and water efficiency (the root factor affecting onset and mitigation of salinity). As such, it can also help define the potential of an area to face agricultural production.

To demonstrate the validity of regenerative practices and assess the efficacy of FTT, the study has been conducted around 3 main research questions:

- How can general regenerative agriculture interventions help mitigate salinity and strengthen revenues in Egypt, Jordan, and Iraq?
- How can FTT help assess these processes?
- What would this mean for policy development in the 3 countries?

To answer these questions, six farms have been chosen and action has been drawn to:

- Assess business models in Egypt, Iraq, and Jordan facing salinity, based on soil, water and climate conditions.
- Characterize different scenarios governing salinity and prospects to mitigate salinization, while providing an ecologically and financially sustainable land use.

- Recommendations on regenerative practices and digital tools/FTT in saline areas, and follow-up actions.

1.4 Project data

The ability of any tool to predict the outcome of a situation or mutation is built on the quality of the underlying data on which the tool has been built. In this case, the ability of the FTT to accurately predict outcomes is built on its extensive underlying database of scientific studies and farming projects that provide all kinds of data on farm performance, layout, crops & tree characteristics, etc. Interactions are governed by underlying (bio)physical laws.

The project also uses field data from 6 farms in Egypt, Jordan, and Iraq, such as for instance water use, water quality, yield, and crop varieties used.

1.5 Project limitations

This project aims to evaluate the impact of regenerative practices on salinity with a DSS tool. In this case, the FTT has been used. FarmTree has been developing the FTT for mostly tropical conditions, and not necessarily for arid regions or predicting salinity. More data and farm cases will improve the quality of the FTT, and its ability to not only supply predictions for a larger landscape scale, but also at a farm level detail. For this project, the FTT was supplied with reliable field data from 6 farms in which regenerative practices and 4C were properly designed and managed. More of this data is required to improve the model for arid and saline conditions.

For this study, a provisional module was made in the FTT to predict crop yields because of soil salinity, and salinity management measures. This Tool has a tree-crop interaction model that forecasts the effect of regenerative agriculture measures (intercropping, tree planting, irrigation volumes, etc.) on yields, biomass, finances, labour, and others. The tool can be accessed online through www.farmtree.earth. However, some assumptions are made, and further work is required to improve the tool.

Nectaerra (www.nectaerra.com) has been applying regenerative practices and customized cover and companion crop mixes (4C) since 2020 for salinity management with good results for different crops. Each farm is unique with its own set of conditions, and proper advice and management is required to get good results. To simplify the design process, in this project three regenerative intervention have been included, where more interventions may be also required.

To conclude, the results are valid for the chosen crops and the farming interventions, but more work must be done to broaden the horizon and improve the predictive quality of the FTT.

2 Salinity in Egypt, Jordan, and Iraq

For general reference, this Chapter provides a brief background on salinity in Egypt, Jordan, and Iraq.

2.1 Introduction

The MENA region, comprising of 21 nations, is situated in diverse agroecological settings ranging from Mediterranean to hyper-arid climates. The region faces different climatic constraints: aridity, recurrent drought, desertification and salinization, the latter also in part human-induced (R. Choukr-Allah et al., 2023). Salinity is a rising issue worldwide and certainly also in the MENA region where the dominant agricultural areas are threatened by saline soils and water resources. This situation impacts farming and livelihood to a great extent, and finding solutions and approaches to curb salinity is ongoing. Typically, these are sought in technology, such as the development of more salt tolerant crop varieties and more efficient irrigation methods.

Soil salinity is a phenomenon that can happen in any climatic conditions, and it is not solely determined by the arid/semi-arid climate of a region. However, when combined with human activities like deforestation and unsustainable urbanization, arid regions are more susceptible to soil salinity. In such areas, the lack of adequate and dependable rainfall exacerbates the problem, making it harder to remove the salts from the soil.

Due to the dry climate in the MENA region, about 40% of the cropped area in the region requires irrigation (Haq, M.A., et al., 2022). The soils currently used for farming are severely degraded to the point where their productivity is estimated to have been reduced by up to 30 to 35% of potential productivity (R. Choukr-Allah et al., 2023). Losses from salinity alone across the region are estimated at US$ 1 billion annually, or US$ 1,600 to US$ 2,750 per hectare of affected lands (UNEP 2020).

Figures 1 (soil salinity) and 2 (irrigation water salinity) illustrate the degree and distribution of soil and water salinity in Egypt, Jordan, and Iraq. Maps are produced by combining FAO AQUASTAT country statistics on irrigated areas affected by salinization with spatial information on irrigated areas where precipitation is not sufficient to leach away salt residues that are built up in the soil due to irrigation (FAO, 2010). Excess of free salts referred to as soil salinity is measured as Electric Conductivity (EC in dS/m).

For reference purposes, the following section very briefly covers salinity in Egypt, Jordan, and Iraq.

2.2 Soil salinity

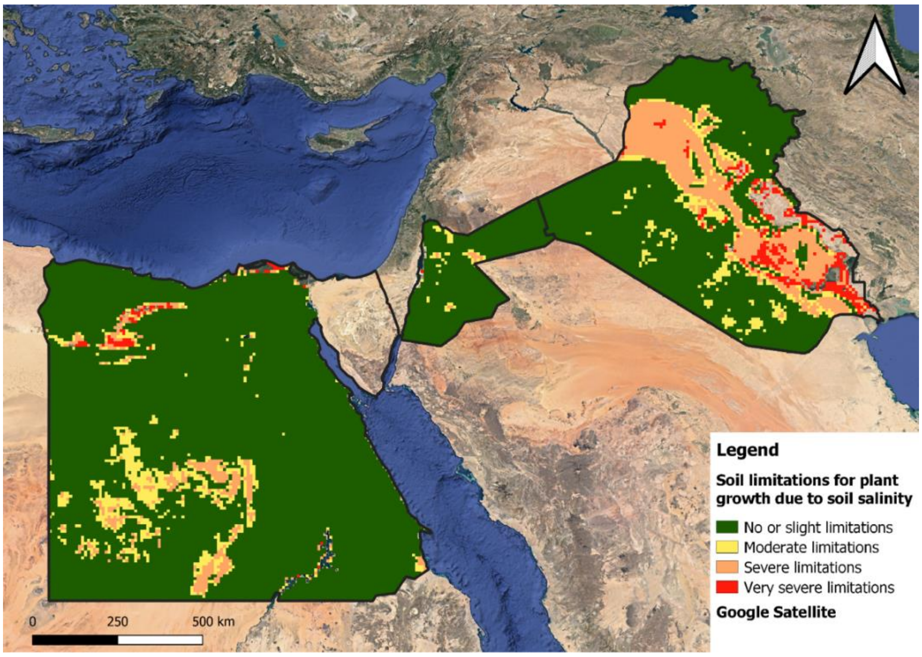

Figure 1. Soil salinity severity for Egypt, Jordan, and Iraq

Four levels of soil salinity are discerned (FAO, 2010):

I. No to slight salinity levels which will create no to little damages.
II. Moderate salinity affects crops through inhibiting the uptake of water.
III. Severe salinity affects growth and reduces yields.
IV. Very severe salinity levels may kill the crop.

Egypt

Most agriculture performed along the Nile and especially Nile delta. Main causes of soil salinity are seawater intrusion, especially in coastal zone of the Nile Delta, high water table level, accumulation of salt in the upper soil layers due to unsuitable irrigation management and inadequate drainage conditions (SALAD, 2023). Saline, saline-sodic and sodic soils have a strong presence in the Nile delta land and represent an average of 37% of the total cultivated soils. The north delta contains the highest area of saline and saline-sodic soils reaching 46% (Mohamed 2016). FAO (2005) classifies 30 to 40% of the soils of the Nile delta as salt affected. Soils are typically moderately saline (4-8 dS/m, ECe) and highly saline (8-16 dS/m) (DE Al-Agha, et al., 2015).

Jordan

Most agriculture is performed in the Jordan Valley. About 63% of soils in the Jordan Valley are saline, out of which almost 46% are moderately to strongly saline (Ammari et al, 2013).

Iraq

Most agriculture is performed in the Mesopotamian basin between the Euphrates and Tigris rivers.

Of the approximately 9.5 million hectares arable land (FAO, 2021), around 1.3 million hectares (14%) is slightly salt-affected, and 6.7 Mha (71%) is severely salt affected (R. Choukr-Allah et al., 2023).

2.3 Water salinity

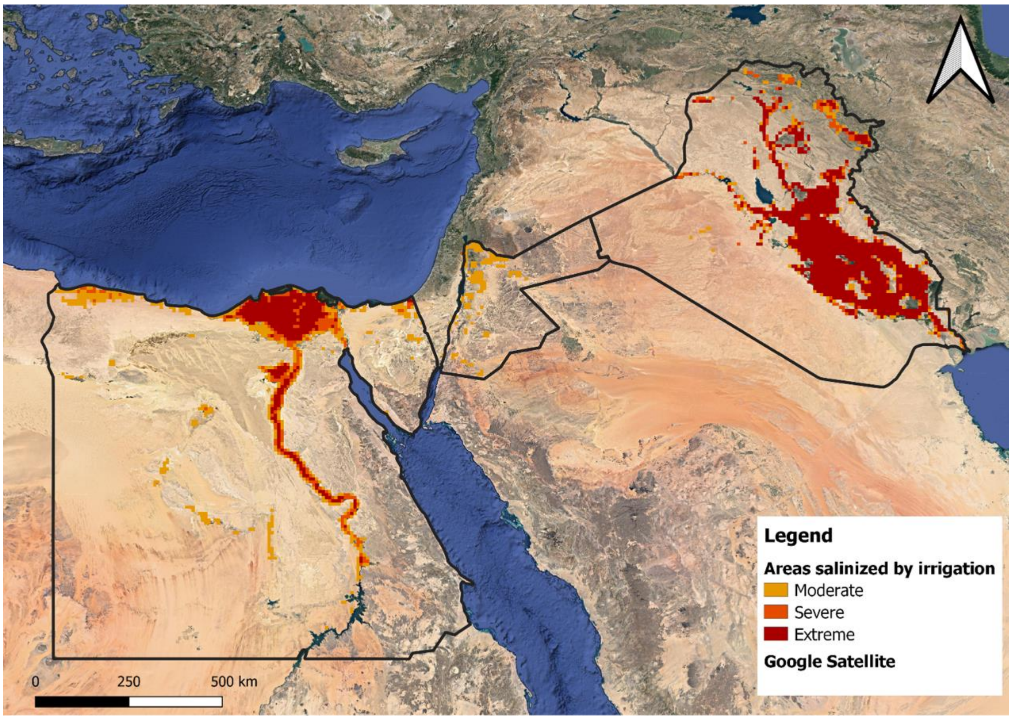

Figure 2. Water salinity severity for Egypt, Jordan, and Iraq

Three levels of water salinity are indicated: moderate, severe, and extreme. These salinities have a medium to high degree of inhibition on physiological processes in crops.

Egypt

The Nile provides almost all water for agriculture in Egypt and has a low salinity. However, groundwater and agricultural drainage water are important causes of water salinization. The degree of salinity can vary considerably throughout the Delta (El-Agha et al, 2020).

Jordan

The Jordan Valley itself follows the Jordan River from the Dead Sea in the south to the Sea of Galilee in the north. All three major water bodies are undrinkable due to high salinity and pollution, or inadequate amounts of water remaining. The salinity of the Lower Jordan River has risen dangerously up to 5400 mg Cl/L in summer 2001 (Farber et al., 2004).

Iraq

The country is currently facing a serious water shortage problem. This problem is expected to be more severe in the future where the supply is predicted to be 17.61 billion Cubic Meters (BCM) in 2025 while current demand is estimated to be around 66.8 BCM. It has been estimated that the Tigris and Euphrates River discharges will continue to decrease with time, and they will be completely dry by 2040 (Al-Ansari, 2013). Low land elevation, groundwater and seawater intrusion and reducing river discharges are main factors contributing to water salinization. For example, the Euphrates River has seen a salinity increase from ~450 ppm (1980's) to ~1200 ppm (2009) (JICA, 2016).

3 Project methodology

3.1 Work process

The project methodology was as follows:

1. For each farm, 2 farms were selected to assess the differences between a business-as-usual (BAU) approach, and a more regenerative approach based on using customised cover and companion, mulch, windbreaks, and resistant varieties (RV).
2. For each farm, field results were collected on crops, water use, management practices and salinity levels for the BAU and sustainable intervention.
3. For each farm, the FTT was used to assess and validate field results for yield production and crop suitability for salinity.
4. For each farm, crop yield and salinity suitability were predicted for a longer duration running up to 35 years. This long duration is only added to estimate net present value of the farm in the future, with all other factors remaining equal.

3.2 Farm selection and interventions

The selection of farms focused on three specific locations in the MENA region, where Nectaerra, FarmTree, and/or WUR were involved in recent on-site projects and activities. These fields were selected because of the prevalent issue of high salinity. In addition, the inclusion of farms from different countries serves to validate the FTT and evaluate its effectiveness across different locations, crops, and management styles.

The following farms were selected, with different crops in each farm:

Table 1. Selected farms and crops

	Egypt	**Egypt**	**Jordan**	**Jordan**	**Iraq**	**Iraq**
Farm location	Cairo	Baltim	Karameh	Ma'an	Az Zubayr	Mosul
Crop	Mango	Tomato	Olive	wheat	Barley	Potato

The background of the sustainable interventions were regenerative farming practices implemented by Nectaerra in those 3 countries over the past years. The three regenerative measures were:

- Customized cover and companion crop mixtures
- Straw mulching and wind break
- Resistant varieties (more climate or salt tolerant crop varieties were included on all farms)

These practices were used on “experimental” (sustainable) plots and compared to the “business as usual” (BAU; unchanged) scenarios using the FTT.

The scenarios that were analysed with the FTT are explained Table 2.

Table 2. Analysis framework for farm interventions

Country	Location	crop	Scenario analysed
Egypt	Cairo-Alex Desert Road	Mango	1. Crop + BAU 2. Crop* + 4C 3. Crop + 4C + mulch
	Baltim, Kafr El Sheikh	Tomato	1. Crop + BAU 2. Crop RV + 4C 3. Crop RV + 4C + mulch

Jordan	Karameh, Jordan Valley	Olive	1. Crop + BAU 2. Crop RV+ 4C 3. Crop RV+ 4C + mulch
	Ma'an	Wheat	1. Crop + BAU 2. Crop RV + 4C 3. Crop RV + 4C+ windbreak
Iraq	Mosul	Wheat	1. Crop + BAU 2. Crop RV + wind break 3. Crop RV + 4C
	Basra	Potato	1. Crop+ BAU 2. Crop RV + wind break 3. Crop RV + 4C

*One variety was used

3.3 FTT (FarmTree Tool)

Developed by FarmTree BV, FTT help projects the performance of diverse agro systems. The tool generates scenarios' projections in time graphs for a variety of economic, social, and environmental indicators. Specifically, the Tool can help in realising Cost-Benefit Analyses of farming systems and in predicting developments on several sustainability indices: soil fertility, erosion resistance, carbon sequestration, and water efficiency (the root factor affecting onset and mitigation of salinity). All predictions are a consequence of the landscape and management practices adopted by the land user, and the data that is fed into the model.

The tool is based on an extensive underlying database of scientific studies and case studies that provide all kinds of data on farm performance, layout, crops & tree characteristics, etc, and soil-land-atmosphere interactions governed by (bio)physical laws. The tool has been developed for the tropical region, where it allows a full range of predictions from CBA, i.e., crop yield and revenues, to the sustainability factors. It is an important step into the process of showing hesitant farmers how and what practices best fit their socio-economic-environmental conditions. Forecasts can be made of CBA and sustainability indices for periods up to 50 years from present.

The predictive quality of the tool improves as more information is added. If the range of conditions and performance vary considerably between farms in a certain region, the tool will essentially provide a better reliability for regional trends than for individual farms.

For this study, a new salinity module was developed. The choice that was made was to express salinity in the model as the "suitability to salinity" of a crop system to deal with salinity. Suitability to salinity is the degree to which a plant can perform its normal physiological functions without being affected by salinity problems. The higher the percentage, the better the crop's ability (or health) to resist salinity levels in the field.

The module is based on various literature and data where salinity in agriculture is studied. The module is based on direct relationships of salinity with the climate, soil structure, humidity, temperature, resistant varieties, and fertiliser inputs. Other indirect relationship, such as with 4C, mulch and windbreaks, are also considered, but their relationship to each other is less well defined in literature. In practice, each parameters mentioned has a certain degree of influence on the final value of Suitability of Salinity.

Principally, the higher the water and soil salinity, the lower the (cropping system's) Suitability to Salinity (STS). The STS in fact describes as quality that is typically also associated with some seed varieties marketed as more "salt tolerant" (although this term is misleading). Water and soil salinity values were kept unchanged, as average value, both in summer and winter. Also, the volume of irrigation water was not changed throughout the seasons.

To properly predict the relationship between salinity and the other sustainability indices (for example soil fertility) requires more development and study data, and for this reason, the outcome of the model in this

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project was limited to crop yield vs. the suitability to salinity. Crop yield is the quantity in ton/acre produced by a crop over a growing season.

In the future, it would be interesting to improve the model and understand the relationship with the other sustainability indices (soil fertility etc.) and how these indices interact in a qualitative and quantitative way.

4 Results

4.1 Prediction results

For each farm, six in total, the effects of regenerative practices and of business as usual (BAU) practices on crop production under saline conditions are shown in two graphs. The graphs depict crop yield resp. Suitability to Salinity (STS) over time. The higher the STS, the more the crop will be able to perform its normal function (despite salinity) and reach its optimal yield. This is not a linear relationship, as seen in

The results for all farms are shown in the Appendix. All results showed better suitability to salinity and a progressively higher yield for sustainable practices compared to BAU. The results for Ma'an (wheat) en MK Farm (mango) are shown and explained below.

Jordan, Ma'an, Wheat

For Ma'an farm we can notice how RV, 4C, and 4C plus a windbreak increases the Suitability to Salinity with a range between 10-20%, increasing wheat production and improving its climate change resilience. Regarding yield, in the long-term windbreaks significantly increase the production (ton/ha) of wheat crop, improving yield from 3 ton/ha to 4 ton/ha over a period of 35 years.

This long duration is only added to estimate net present value of the farm in the future, with all other factors remaining equal. It is an existing function of FTT to look quite far into the future for investment decisions, but naturally, factors such as climate, salinity and other farm characteristics may potentially change considerably over time. Regardless, it may be useful to have that prediction and to work on further improvements. Practically speaking, a 10 to 15 year period is a desirable and reliable interval on which to build farming decisions. Beyond this horizon the data can be used to assess the net present value of an enterprise or company.

In this case, the windbreaks and 4C also produce biomass that have additional value, for instance as fodder, but this yield or value is not expressed or quantified at this time. Considering a 35-year timeframe, 4C increase yield from between 0.3 to 1.25 ton/ha.

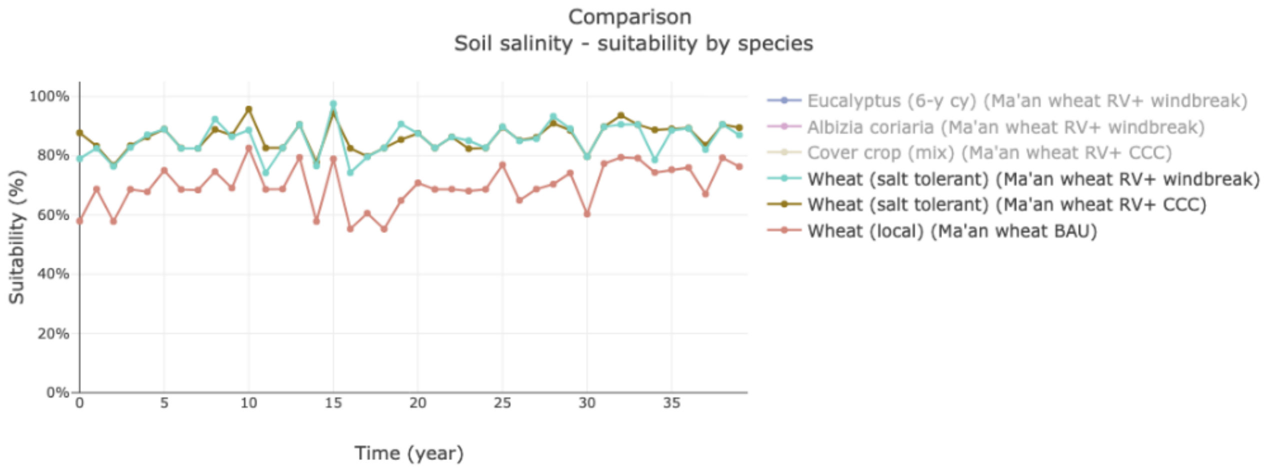

Figure 3. Ma'an Farm, Jordan, wheat Suitability to Salinity in time using the FarmTree Tool for 2 regenerative and 1 BAU scenario.

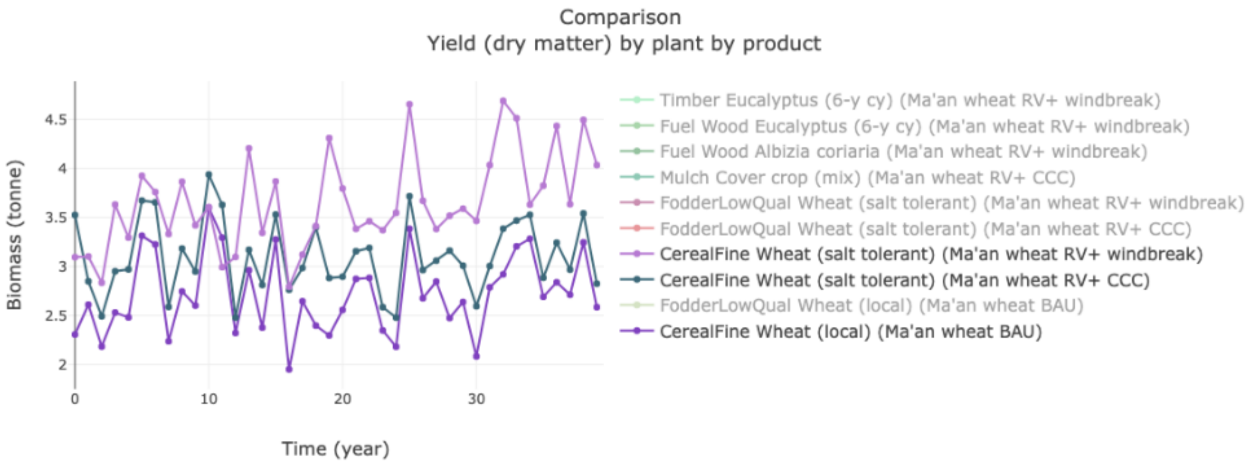

Figure 4. Ma'an Farm, Jordan, wheat yield in time using the FarmTree Tool for 2 regenerative and 1 BAU scenario.

Egypt, MK Farm, Mango

MK farm is an Egyptian mango producing farm who implemented 4C and mulch as sustainable approaches.

The results obtained with FTT are in line with the expectations and follow actual field data. A significant difference is shown when comparing sustainable practices against BAU methods. Generally, it is possible to observe how sustainable practices are helping the farmer in creating a better living quality environment for plants to grow, which is reflected in higher Suitability against Salinity. Is clear how the effects of climate change are reduced when regenerative practices are implemented. Suitability against Salinity lies at around 78% with regenerative practices, versus around 68% for BAU. As also highlighted in the figure, this gap is expected to increase as far as climate change events become more regular and severe.

Regarding mango yield, on field results showed an increase of ~10% during the second year of management. In the model is possible to see how in the first 7 years sustainable practices don't make a significant impact on the crop. This is due to the early age of the mango. On FTT, only when mango reaches full productivity regenerative practices have a significant impact. This is not the case in on field experiments, where we have noticed a higher germination rate and faster development for mango plants surrounded by 4C and mulch.

After the establishment phase, also the model represents a significant difference between regenerative approaches and BAU. Differences in yield can be attested between 0.1 to 0.7 ton/ha. As for the wheat analyses, the graph only compares mango production. If we would also include biomass production from 4C the difference would be much higher. From our on-field experiment at MK farm we obtained about 5 ton/ha of biomass from cover crop cultivation which is in line with other experiment conducted (Ruis S.J. et al., 2019).

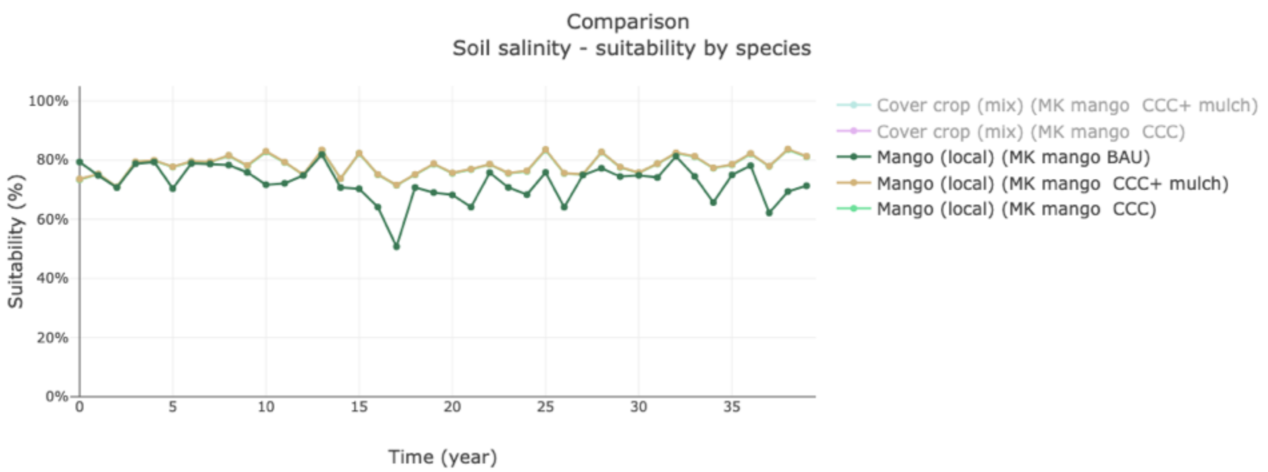

Figure 5. MK Farm, Egypt, mango Suitability to Salinity in time using the FTT for 2 regenerative and 1 BAU scenario.

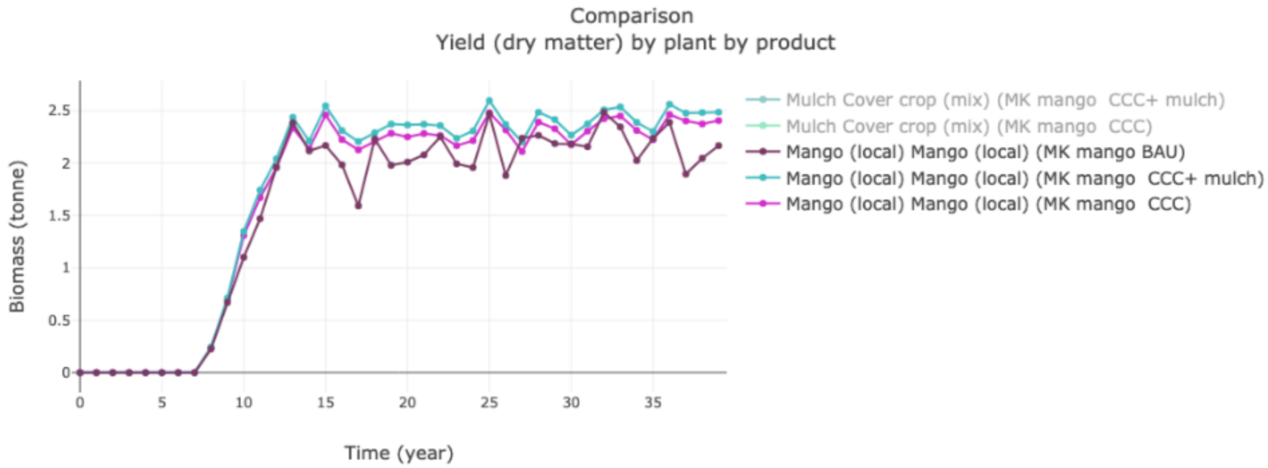

Figure 6. MK Farm, Egypt, mango yield in time using the FTT for 2 regenerative and 1 BAU scenario.

4.2 Validation

During the assessment of the farm data for validation, the same mode of analysis was carried out in all farms. Yields of the regenerative and BAU plots with same area, were collected and weighted separately.

For salinity, the results are based on salinity values recorded during monthly field assessments, in which data on soil temperature, moisture, and nutrient availability were also collected. On-field results are directly correlated with adoption of 4C, mulch, windbreaks, and RVs. On average, the following effects were shown:

- Increase in yield of around 10%
- Decrease in salinity of 0.2-0.4 dS/m
- Reduction in evaporation of 7-12%

These results are presented as ranges because they depend on farms location, starting condition, and varying degree of on-field implementation.

These field results are supported by numerous literature findings: in similar cropping systems, adoption of cover crop can benefit main crop production by a range up to 10-12% (Bird, P.R., 1998; Nielsen, D.C., 2016; Hartwig, N.L. & Ammon, H.U., 2017; Mitchell, H.C., 2019; Kučera et al., 2020). Here, the effects of mulch and windbreak are related mostly to reduction of soil evaporation through lower soil temperature and higher soil humidity. This is a direct effect of higher soil mulch cover and Leaf Area Index (LAI) (Jia, Q., & Wang, Y.P., 2021; Haj-Amor et al., 2022).

4.3 Discussion

According to the results of the model, 4C, mulching and windbreaks had a positive effect in ensuring higher plant growth suitability, and consequent yield. As would be expected, when comparing the model results for yield and suitability to salinity (STS), 4C and windbreaks had a greater effect than mulching. It is therefore important to clarify that the latter had a smaller impact than what was recorded during the field trials. The same is true for 4C and windbreaks regarding STS and crop yield. Bigger impacts are seen from the RVs. They were responsible for most of the difference in yield and STS produced by the model. The explanation for this lies in the model's dynamics and the way parameters influence each other within the model. The field data clearly show a greater impact of the sustainable practices when compared to the model results, so this is something to investigate and improve in the FTT in the future.

Regarding the calibration of the model, RVs are the easiest parameter to analyse and to correlate with the parameters within the FTT. This is due to the more limited benefit offered by RV in the open field. Other sustainable practices such as 4C, windbreaks and mulching offer further ecological services, but their role and benefits are more complex when included in a cropping system and analysing many different factors together. In other words, despite the positive results reported by the field data, the model is not yet able to fully show the degree of effectiveness of 4C, mulching and windbreak on the two parameters analysed (crop yield and STS). This is because clarifying and quantifying the impact of these practices is highly complex.

In the future, to improve the predictive quality of the model for sustainability practices (such as 4C, mulch and windbreaks) it is also important to link the impact of these sustainable practices with other sustainability indices in the model. For example, cover crops can help build organic carbon in the soil, but at present the “carbon sequestration” module in the FTT cannot calculate that.

By utilizing the FTT, decision-makers can enhance their understanding and make well-informed choices for implementing nature-based solutions that lead to successful business cases. The FTT can therefore play a crucial role in guiding policy development. However, it is important to note that the tool itself is not enough to significantly influence this process at the regional or country level. While FTT can be helpful in assessing the potential impact of interventions, it still requires support from a detailed planning process. Before implementing any nature-inclusive solution, conducting a CBA is essential, and the FTT can aid in identifying and quantifying positive impacts.

5 Workshop

An online webinar was organized to disseminate the project to a broader audience.

5.1 Programme and attendees

The webinar consisted of:

- An introduction to the Saline Water & Food Systems (SW&FS) of the NFP and NWP (Nectaerra)
- A short online demonstration of the FTT (FarmTree)
- A brief background to regenerative agricultural practices (Nectaerra)
- An overview of salinity problems in Egypt, Iraq, and Jordan (Nectaerra)
- The project's design, results, lessons learned (FarmTree, Nectaerra)
- Discussion on outcomes and forward actions

Attendees were invited based on local and scientific interest and knowledge on salinity, and present were staff from the Soil & Water Institute (Egypt), Desert Research Center (Egypt), Zagazig University (Egypt), Menoufia University (Egypt) and Salahaddin University (Iraq), in addition to staff from the Dutch Embassies in Egypt, Jordan, and Iraq.

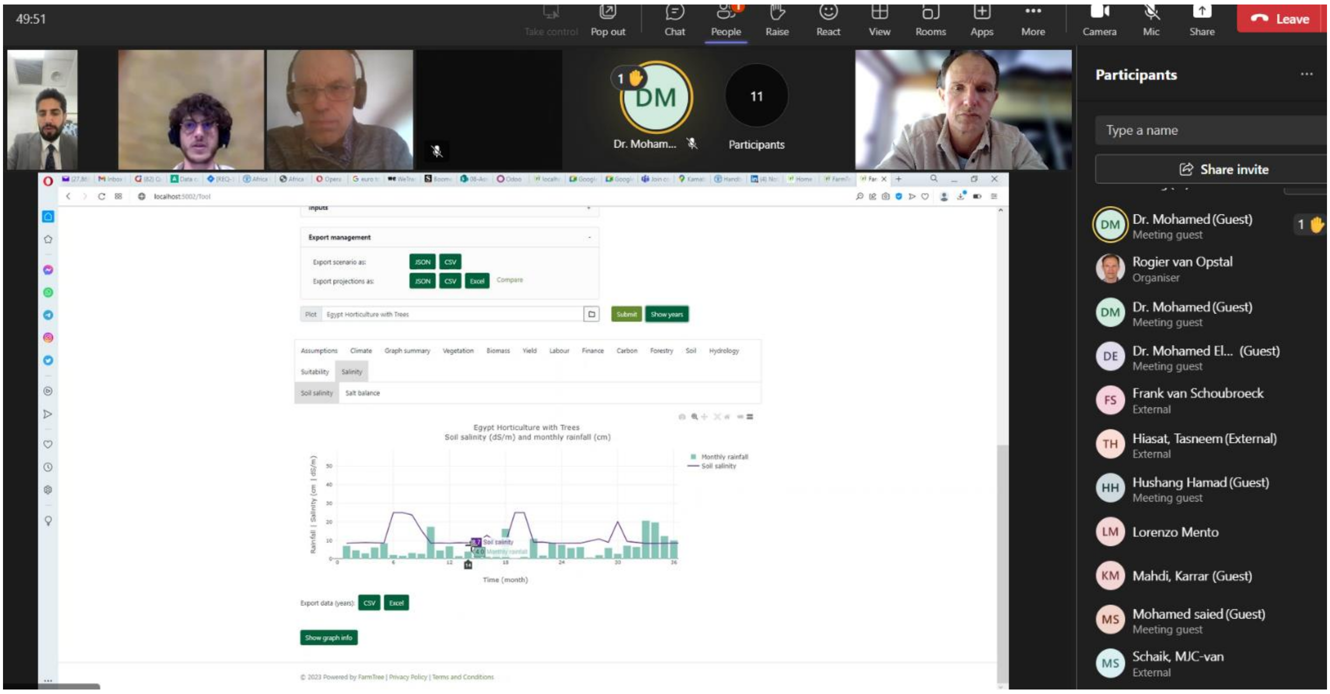

Figure 7. Screenshot of the online webinar in May 2023

5.2 Workshop discussion

Questions were raised about the potential of FTT in assessing farm finances. This is a parameter that is indeed included in the model but was not showed in the results analyse. The aim was to prove the restoration capacity of sustainable practices and their potential impact on soil, yield, and environment. Moreover, the economics model is not yet completely calibrated with the salinity predictions and must be developed. In the experience of Nectaerra the CBA remains positive, pointing to a case such as MK Farm where the farm itself has been using cover crops for two years since introduction by Nectaerra.

Another question faced the suitability of water requirements during cover crop adoption. During on field experiment we have indicated how well cover crop can perform even on arid soil, having the need of extra water only during the germination and establishment phase (depending on location, 2–3-weeks' time) if the water is not available for "free" by using the excess irrigation water (applicable to both flood irrigation and drip irrigation). After this period, the cover crop's water needs were tuned with the water supply of the main crop. Planting cover crop had an impact on water use efficiency of the farming plot, resulting in more crop per drop. However, the lack of knowledge and culture may be a problem, as farmers see a problem because they think more water may be used.

In reply to one question, it can be said that cover crops can be selected for saline areas and are thus applicable in saline areas such as southern Iraq.

Another question related to the applicability of the regen ag practices and FTT for smallholder. The FTT was established with SME specifically in mind, while the regenerative practices adopted here are all low cost and available to most farmers.

On the use of the tool in a wider perspective, the following interesting perspectives were given:

- The WUR would like tool to help for comprehensive design of a sustainable farm.
- Private companies providing extension services to farmers may benefit from regenerative agriculture practices in combination with the FTT.
- The FTT is interesting if it could be tuned to assess the reduction of fertilizers.
- The FTT may be able to supplement WAPOR, which is collecting hydrological data.

6 Conclusions & Discussion

6.1 Technical conclusions

Regenerative practices are known to improve crop yield when applied correctly, and evidence suggests this is also the case for saline conditions. The FTT was equipped with a salinity module that expresses salinity as a "Suitability to Salinity", defined as the degree to which a plant can perform its normal physiological functions without being affected by salinity problems. The effect on water salinity is currently not determined, and more work is needed to relate differences in water consumption between regenerative and business as usual (BAU) practices, to water salinity.

The FTT can predict the effects of several regenerative practices vs. BAU practices. Both field validation data and the FTT show similar positive results on crop performance under saline conditions for regenerative practices.

However, when comparing the field data to the FTT results, it appears that the model calculates the relative differences between the various regenerative practices and resistant crop varieties incorrectly and not in line with field data. More representative study and scientific data will help to improve the model for (semi) arid and saline conditions, and for different crops, and to properly distinguish the effects of the different regenerative practices. This makes the FTT currently a tool better used for assessing trends and longer-term impacts of several regenerative practices, then for high making highly detailed predictions for a specific farm. This will improve as more farm data is added, specifically for semi-arid and saline affected areas and farms that have been the focus of this study.

An important improvement would be to link salinity and water use to all sustainability indices (soil fertility, carbon seq. etc) and to the cost-benefit module (incl. yield) also contained in the FTT. This would make FTT a powerful tool that is able to link and assess farms economic, environmental, and productivity problems all at once, while promoting nature-based solutions as a remedy strategy. However, this firstly requires further research on all those relationships between salinity and the other factors and indices. Although much can be gained from literature and scientific papers, especially for salinity this will inevitably also require new field research.

6.2 Research answers

The three research questions are answered:

1. How can general regenerative agriculture interventions help mitigate salinity and strengthen revenues in Egypt, Jordan, and Iraq?

   Regenerative intervention can ensure a high level of production and buffer climatic stress that can negatively impact crop development, generating yield variability throughout the years. Higher soil water retention, improved biology, and microclimate creation are just some of the multitude benefits sustainable interventions will provide to a farm. Salinity can be controlled and mitigated by the improved soil structure, higher water retention in the rootzones, and higher crop water efficiency. Revenues will be strengthened by reducing yield variation throughout seasons and improving secondary sources of income, thanks to higher different number of plants grown per area.

2. How can FTT help assess these processes?

   The FTT can assist in evaluating the benefits and estimating positive outcomes of sustainable interventions in terms of time (seasons and years) and impacts (yield quantification), when properly calibrated with field data from the area it is used in. Its precision requires calibration and validation with on-ground data, and this is currently specifically the case for tropical agriculture with trees. The more FTT is calibrated with local field data for semi-arid regions (e.g., Egypt, Jordan, Iraq), the more reliable it will become and the more functions (such as soil fertility, carbon sequestration) can be included in its predictions. FTT proves helpful in the decision-making process concerning high-level cultivation or land use decisions that affect cost-benefit over time. FTT can help weigh the impact of regenerative interventions over time for various factors (such as soil fertility and carbon sequestration), which is crucial to understand. It can provide valuable insights into how the environment, salinity, and water levels may affect new cultivations and the impact this has on farm economics and climate resilience. While the FTT is less suited as a design tool for actual (farm) implementation, it does offer perspective on the effects of regenerative practices if it has been properly calibrated for the specific area and is used by someone experienced in implementing regenerative agriculture.

3. What would this mean for policy development in the 3 countries?

By utilizing the FTT, decision-makers can enhance their understanding and make well-informed choices for implementing nature-based solutions that lead to successful business cases. The FTT can therefore play a crucial role in guiding policy development in areas where FTT has been calibrated and provides a high level of accuracy. FTT can be a tool used in a detailed planning process aimed at understanding the potential of an area and designing interventions at a regional or country level. In such a process, FTT is most useful in assessing the potential impact of nature-inclusive interventions from a financial (the CBA module) and ecological point of view, when fully functional for an area.

By utilizing the FTT, decision-makers can enhance their understanding and make well-informed choices for implementing nature-based solutions that lead to successful business cases.

6.3 Recommendations for follow-up and capacity development

We propose a series of activities for successful introduction of regenerative agriculture practices and the use of the FTT to understand, control and mitigate salinity:

A. Pilot studies and tuning of FTT

On-farm pilots are necessary to collect the information required on salinity and the relationship with different regenerative (and good agricultural) practices, environmental indices (e.g. soil fertility) and farm cost-benefit. FTT would then assist in the design stage, and a monitoring and evaluation process would guarantee the information coming back into the FTT.

Our preference is to develop the events in partnership with organisations such as FAO or international research institutes, in a way to increase visibility among potential users for using FTT as a support tool for policy development.

B. Capacity development

To transfer knowledge to users, demonstration and training events with farming communities and other users are a crucial path. Under those conditions FTT can be implemented with high degree of success and can positively change how the tool is perceived and used. Several options we are currently considering are:

- A series of free online webinars and physical workshop to demonstrate how regenerative agriculture and FTT work, and to show potential benefits to farmers. Hands-on training using practical examples and case studies are required to engage users, and take full benefit of their questions, experiences, and network for potential new users.
- Social media and general PR support, such as promotion at conferences and (field or indoor) events, under the direction of NFP and NWP.
- Educational content (videos, tutorials etc.) can be elaborated about regenerative agriculture and FTT on the Nectaerra and FarmTree websites, and perhaps at NFP, NWP, to explain and showcase regenerative agriculture services and tools, and provide access to the FTT for users interested in a trial.

Nectaerra and FarmTree are currently developing a further plan for those activities.

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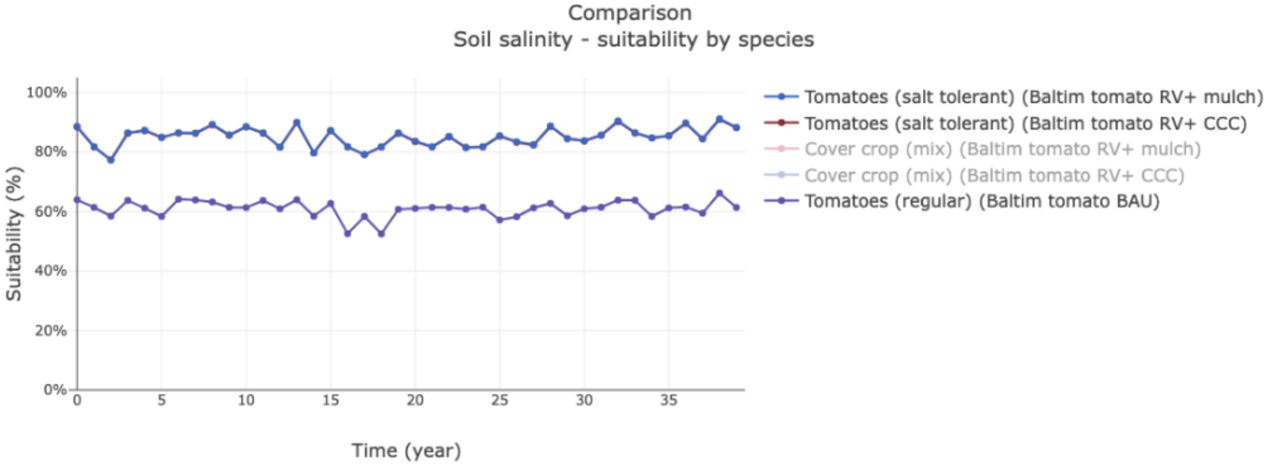
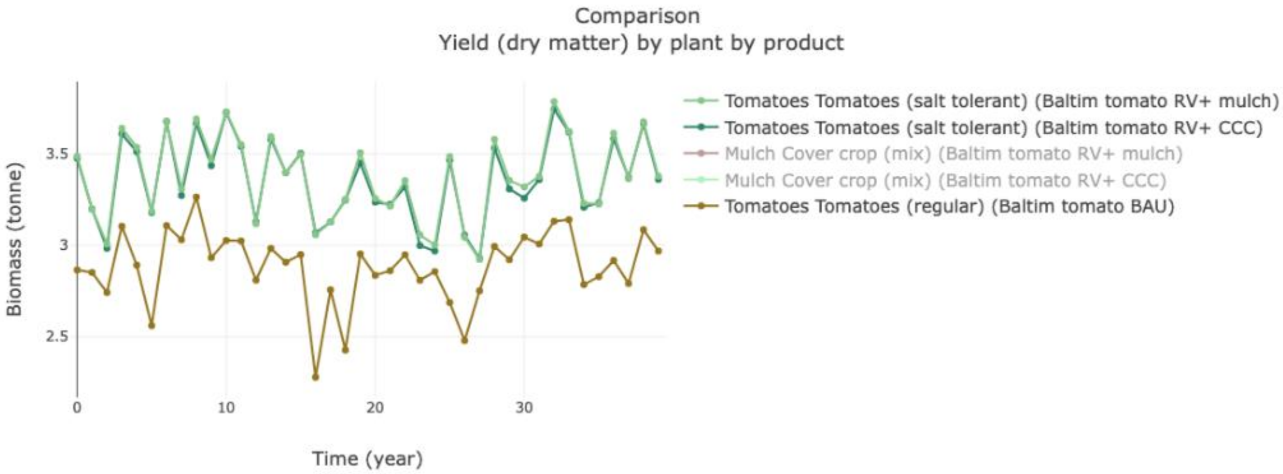
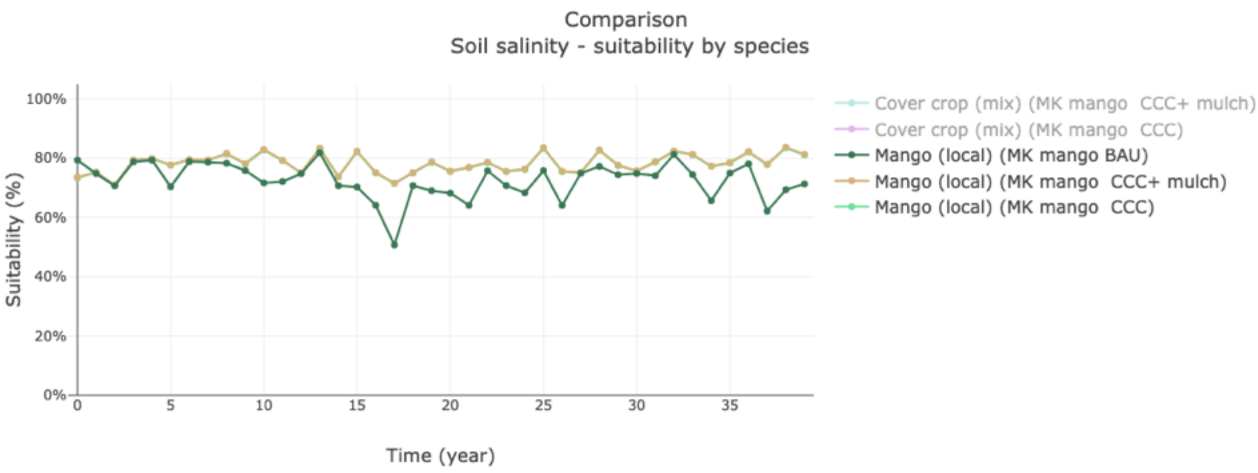
8 Appendices

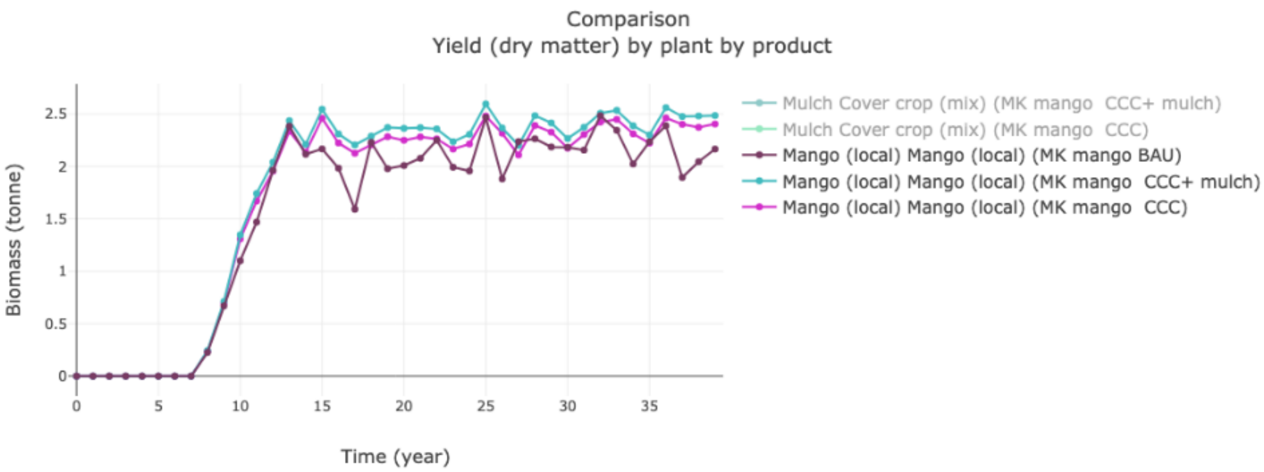
A. EGYPT, Baltim Farm, Tomato



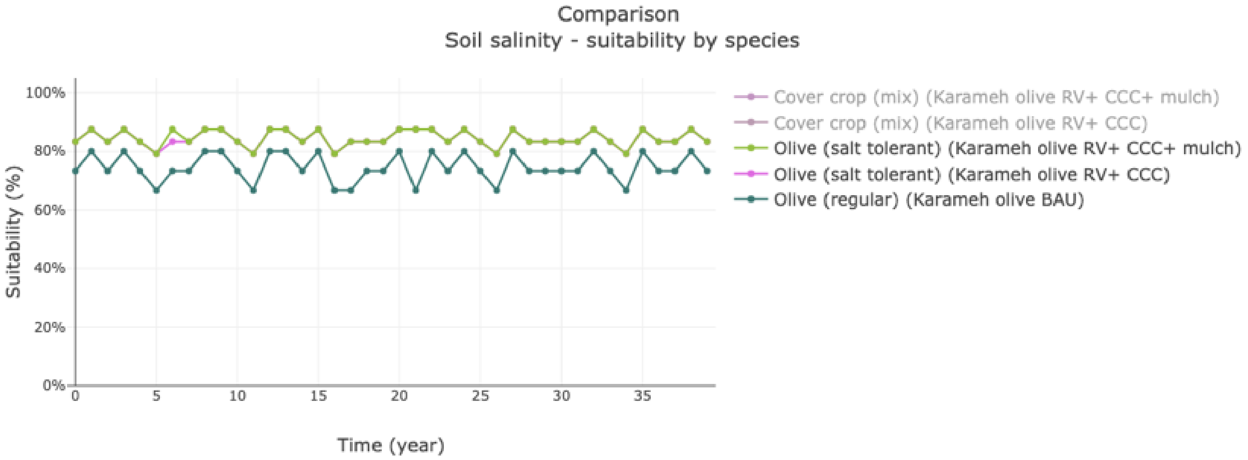


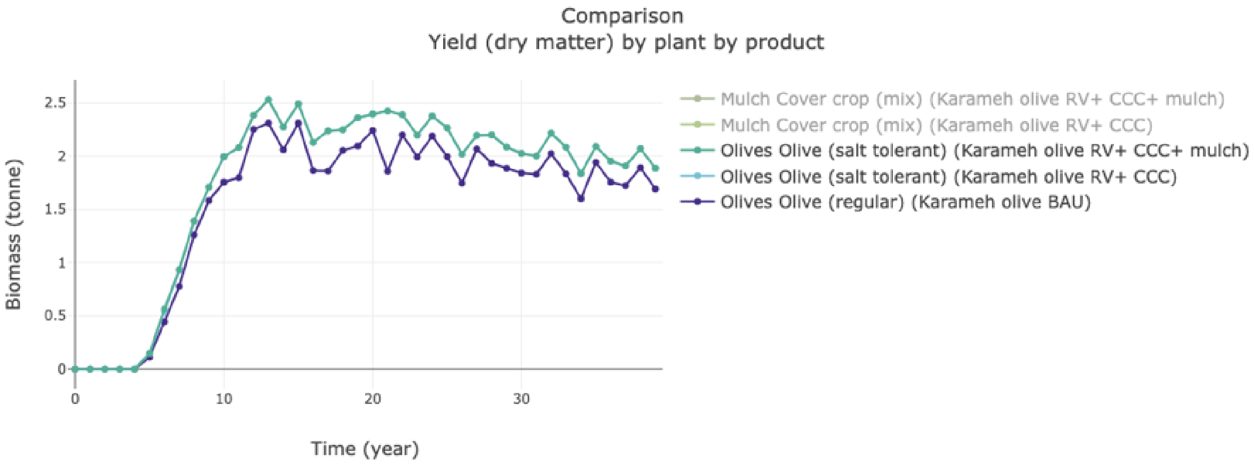
B. Egypt, MK Farm, Mango



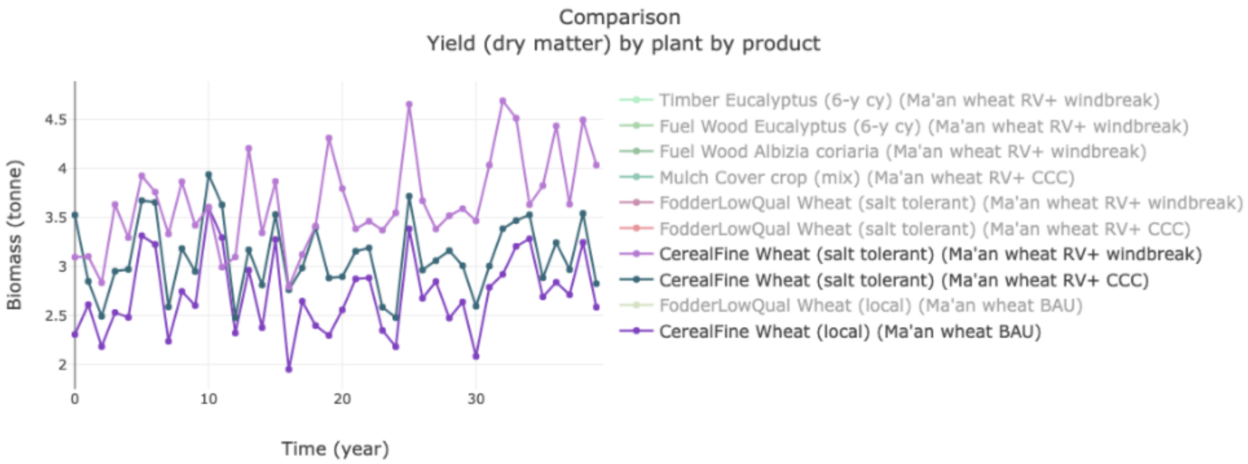


C. Jordan, Karameh, Olive

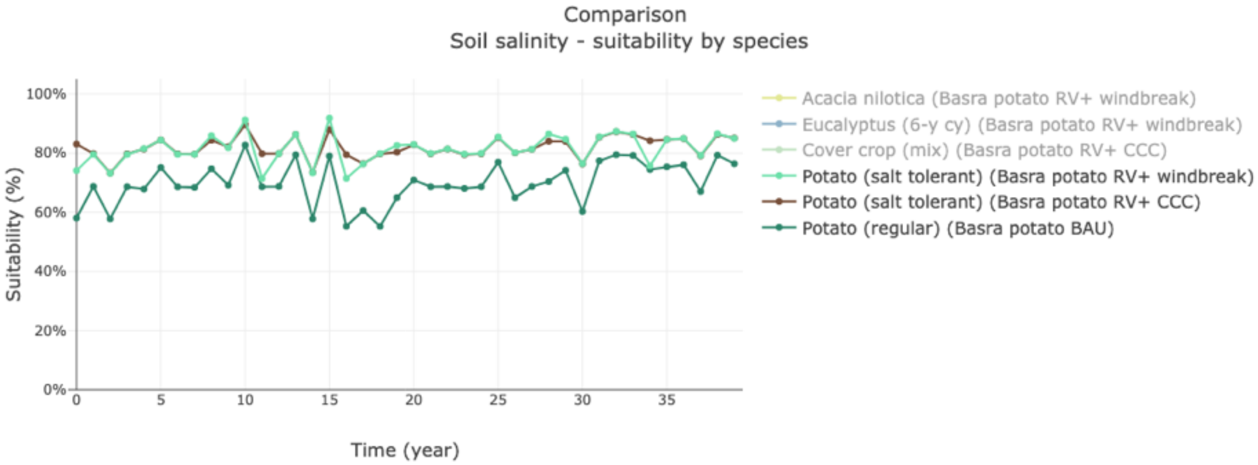


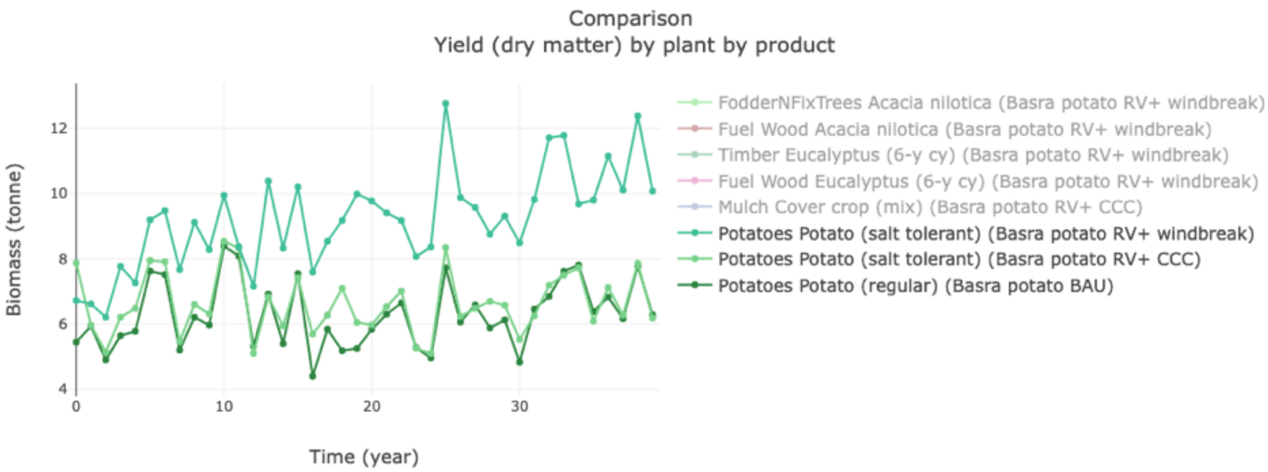


D. Jordan, Ma'an, wheat



E. Iraq, Basra, Potato





F. Iraq, Mosul, wheat