7 Cost or Benefit?

Estimating the Global Economic Potential of Saline Agriculture

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7.1 INTRODUCTION

Although there is no agreement on a single definition of degraded land, researchers consider it to be land that has lost some degree of its natural productivity due to human-caused processes (WRI 2018). Globally, salinity is regarded as one of the most widespread causes of soil degradation. One of the promising adaptation measures to this pressure is saline agriculture, understood to be “profitable and improved agricultural practices using saline land and saline irrigation water with the purpose to achieve better production through the sustainable and integrated use of genetic resources (plants, animals, fish, insects and microorganisms) avoiding expensive soil

recovery measures” (Aslam et al. 2009; Ladeiro 2012). Our previous study (Negacz et al. 2019) has shown that there are 420 Mha of saline soils in the world, of which 16 Mha have at least 500 mm of water available annually (including rainfall and irrigation) that could be potentially used for agriculture. However, there is a lack of a comprehensive overview of the economic potential of saline degraded lands. To address this challenge, this study provides one of the first estimates of the economic potential of saline degraded lands for food production.

One of the first assessments of global costs of salinity was proposed by Ghassemi et al. (1995), who calculated that the global income loss due to salinity was about 11.4 billion USD per year in irrigated agriculture and 1.2 billion USD per year in non-irrigated areas. Further research focusing on the cost side of agricultural production was conducted by Qadir et al. (2014) who presented a comprehensive overview of costs of salinization. Other publications have often adopted a case study approach resulting in economic values for specific regions or sites (Kabir et al. 2018a,b,2017).

The main research question of this study is: what is the potential of saline degraded lands for food production, given the growing knowledge on salt-tolerant crops? We address it by estimating the economic values of saline degraded lands through the ecosystem services valuation methods (being food provision in our case). Ecosystem valuation helps in improved natural resource allocation by showing the full social costs and benefits of goods and services provided by ecosystems (Van Beukering et al. 2015). Providing an answer to our research question enables further exploration of the total value of saline agriculture on the global level and assessing its impact on food production.

7.2 RESEARCH METHODS

Food provision is an ecosystem service which allows applying direct market valuation methods. For this project, three valuation methods were applied to obtain the most comparable results.

7.2.1 META-ANALYSIS METHOD

Meta-analysis is a research method employing analysis of the data from independent primary studies referring to a chosen topic (Koetse et al. 2015). As a first step of the meta-analysis, we conducted an in-depth literature review to identify the data sources for further investigation. This revealed that the literature addressing salinization potential could be categorized into three groups: (1) evaluating geophysical properties and processes including climate, (2) studies looking at salinity effects on plants and (3) salinity management techniques based on case studies. Articles including valuation appeared rarely. Secondly, we identified studies which report the added value of saline agriculture, operationalized as additional income or profit, for the most salinized areas on each continent. Studies on aquaculture, saline pastures, biofuels, halophytes and greenhouse experiments were excluded as they address different markets. As a result, we selected six studies for further comparison. Third, the

values reported in each study were converted to USD per hectare and adjusted for inflation with 2019 as the reference year. Finally, the average value was calculated based on the chosen studies. The average added value per hectare was multiplied by 16 Mha, a total surface area of saline degraded lands with an $EC_e \geq 4$ dS/m and with water availability over 500 mm annually (Negacz et al. 2019). Soil salinity is usually expressed as the electrical conductivity of the saturation extract of the soil (the EC_e) expressed in dS/m (UoC 2020).

7.2.2 COST-BASED METHOD

The cost-based valuation was derived from values obtained in the meta-analysis done by Qadir et al. (2014). This study involved 14 articles reporting costs of salinization. The reported costs of saline land degradation were mostly crop yield losses, in terms of biophysical output (e.g. t/ha) and/or in monetary terms (e.g. USD per hectare). The costs included in that analysis were opportunity costs, production losses, replacement costs, transaction costs, market prices for required services and mitigation costs (Qadir et al. 2014). Building on these results, we adjusted the average cost for inflation with 2019 as the reference year. Similarly, as for added value, the average cost per hectare was multiplied by 16 Mha, the total surface area of saline degraded lands with an EC_e above 4 dS/m and with water availability over 500 mm annually (Negacz et al. 2019).

7.2.3 MARKET PRICES METHOD

The market price method uses the prices of goods on markets to determine the value of ecosystem services, which in this case is food provision through saline agriculture. This method focuses on the quantity (Q) and quality of goods, represented as a field composition in our case (w). We present the value as revenue (R) which equals the quantity of the production multiplied by the price (P): $R = Q \times P$. Since the costs of saline agriculture are rarely reported, the costs could not be calculated. The process was: first, to determine the quantity we selected six conventional vegetable crops (potatoes, carrot, onion, lettuce, cabbage and barley) of which varieties exist that show good yield potential at the salinity levels relevant to this study (de Vos et al. 2016). The yields of these crops were obtained from FAOSTAT (2018). Second, we established a composition on our hypothetical global field (share of the crops on 1 ha). Based on FAOSTAT, we assigned a global area of cultivation per crop. Further, we allocated the corresponding weights to the crops (w_1 to w_6). Third, we derived average producer prices per ton for each crop based on available data in FAOSTAT. Fourth, we calculated the total revenue (TR) according to the equation: $TR = (q_1 \times w_1 \times p_1) + \dots + (q_6 \times w_6 \times p_6)$. The calculations are presented in Table 7.1. The total revenue was multiplied by 16 Mha, the total surface area of saline degraded lands above EC_e 4 dS/m with water availability over 500 mm annually (Negacz et al. 2019). Based on the total revenue, we calculated the revenue with 90% and 50% yield resulting from the impact of salinity.

TABLE 7.1
Calculations for the Global Revenue Based on the Market Prices (in USD)

Crop	Yields (t/ha) (q)	Share in Global Area of Cultivation for Six Analyzed Crops (w)	Yield (t/ha) (q) Adjusted per Weight (w)	Prices (p) (USD/t)	Revenue per Crop (q × p)	Revenue Scaled (q × w × p)
Potatoes	21	0.23	4.89	423	8859	2066
Carrot	35	0.02	0.53	667	23573	354
Onion	19	0.07	1.28	492	9438	631
Lettuce	21	0.02	0.36	1399	30024	506
Cabbage	29	0.03	0.92	561	16128	516
Barley	3	0.64	1.88	283	834	531
Total average yield per hectare			9.86		Total revenue per hectare	4604

7.3 RESULTS

7.3.1 META-ANALYSIS

Our meta-analysis revealed that economic analysis of saline agriculture is scarce. While studies often report changes in yields, they rarely refer to economic categories, such as cost, revenues and profits. [Table 7.2](#) presents six studies from four continents which allow the calculation of an average added value (income or profit) per hectare. They range from 209 to 654 USD, with the Australian case being an outlier; in this example, a calculation was made of the benefits of saline agriculture to a hypothetical farm that also grew other crops and pastures. Across all cases, the average added value per hectare was 383 USD.

TABLE 7.2
Meta-analysis of the Added Value of Saline Agriculture

Author	Year	Country	Area Studied (hectare)	Calculated Added Value per Hectare in 2019 (USD)
Lefkoff and Gorelick (1990)	1990	USA	820	396
Wang et al. (2013)	2013	China	367	570
De Vos et al. (2021)	2021	Bangladesh	n.a.	209
Vyshpolsky et al. (2008)	2008	Kazakhstan	3	654
Ali et al. (2001)	2001	Egypt	400	227
Khan et al. (2003)	2003	Australia	306	239
Average				383

The average value added per hectare multiplied by the global area of saline soils above ECe 4 dS/m with water availability of 500 mm per year (16 Mha) gave a total of 6 billion USD of potential value-added per year.

7.3.2 COST-BASED VALUATION

A recent comprehensive meta-analysis on the costs of salinization has been conducted by Qadir et al. (2014). These authors estimated an inflation-adjusted cost of salt-induced land degradation in 2013 as 441 per hectare. This estimate adjusted for inflation in 2019 equals 497 USD per hectare. For a total area of 16 Mha saline soils, this equals 8 billion USD of costs for salt-induced land degradation. The analysis of costs shows that preventing salinization would result in considerable savings, coming from avoidance of yield loss, mitigation and opportunity costs understood as the value of the trade-off when a decision is made. It may be also considered as an extra income that would remain if the soils were not saline.

7.3.3 MARKET PRICES

Based on crop yields from FAO sources and current market prices we estimated revenue for 16 Mha. The total revenue from this land assuming 100% yield would be 74 billion USD per year. Decreasing yields by 50% or 90% would decrease revenues by 37 or 66 billion USD per year, respectively. These results suggest a large revenue potential, which needs to be contrasted with costs of implementing saline agriculture on items such as seeds and fertilizers. However, no information on these was identified.

In summary, the global economic potential of saline agriculture can be presented as three values shown in [Table 7.3](#).

TABLE 7.3
Comparison of Economic Valuation of Saline Agriculture

Method	Value for 16 Mha in billion USD
Meta-analysis value (added value)	6
Cost-based value (total costs)	8
Market price (revenue)	37–66

These aggregate numbers obtained through different methods show that saline agriculture can be a source of benefits, not only expenses, which we discuss in [Section 7.4](#).

7.4 DISCUSSION

This discussion focuses on three general themes, the threshold of added value per hectare, costs included in the cost-based valuation and several challenges in the market price analysis.

7.4.1 INCONSISTENT AGREEMENT

A lack of articles including economic valuation of the potential of saline degraded lands turned out to be a major issue for our meta-analysis. The available publications are usually inconsistent in terms of the metrics used and they apply diverse

approaches to estimating costs and benefits. This made it especially difficult to bring the reported values to a common denominator and resulted in some more general statements (e.g. measuring added value instead of profit). However, among all the diverse values and methods, there was a certain agreement when it came to the added value of saline agriculture per hectare. The values varied between ~200 and 600 USD depending on the country. We excluded from the analysis a study with 76,000 USD per hectare from United Arab Emirates (Robertson et al. 2019), as it focused on halophytes which have a different market and considerably higher prices than other crops. Lastly, we also decided to exclude studies which provided values for biofuels, pastures, forage and aquaculture, as all these involved different markets.

7.4.2 COSTS OF NOT APPLYING SALINE AGRICULTURE

The cost-avoided valuation method in case of saline agriculture can bring highly diverse results based on the inputs, and whether irrigated or non-irrigated land is considered. Amongst others, the costs included by Qadir et al. (2014) were opportunity costs (forgone agricultural income or alternative activities), production losses (crop response function to salt level), replacement costs (preventing and repairing land degradation), transaction costs (costs of developing and implementing four land and water management plans), market prices (groundwater recharge credits trading, land rents) and mitigation costs (desalination plant). All these cost categories vary in order of magnitude and the solutions that apply. Further studies could produce estimates based on different cost categories. In terms of irrigated and non-irrigated areas, according to the UNCCD Global Land Outlook report on Food Security and Agriculture, at least 20% of irrigated lands are salt-affected and this number may increase to 50% by 2050, (UNCCD 2017). The average cost suggested by FAO is 245 USD per hectare (inflation-adjusted 255 USD per hectare), which would result in 4 billion USD of costs globally when extended over 16 Mha. For both costs and benefits, it would be beneficial to calculate them for different salinity classes as each level of salinity has its own economics. However, a current level of data availability and granularity does not allow for more in-depth analysis.

7.4.3 MARKET PRICES

Our analysis produced an average revenue per hectare, taking into account crop yields, their response to salinity and the market prices of six selected crops. The crop selection and field composition would vary considerably per country, therefore we scaled it to the global area used for each crop cultivation. Similarly, the producer (off-farm) prices are country-specific. Therefore, the international prices and produce quantity resulting from field composition indicate more a direction than a specific number. However, revenues represent only one side of the equation. The costs of implementing saline agriculture on a scale beyond experiments or pilots are presently unknown. The costs of seeds and fertilizers and initial investments in equipment and training led by a multidisciplinary team would vary greatly between locations and amongst crops.

7.4.4 NON-MONETARY VALUES

Finally, very few studies refer to the non-monetary values of improved agriculture in degraded environments for local communities and the environment. These values, often included in ecosystem service valuations, could add to the full picture and potential of saline agriculture. Examples of the studies which pioneer in this regard are the work of Kabir (2016) and de Vos et al. (2021) presented in this book. Including indirect values such as social and environmental costs and benefits in the analysis could be an interesting direction for future research.

7.8 CONCLUSION

This study aimed to investigate the economic value of saline degraded lands based on three valuation methods. Our analysis has confirmed that the values vary considerably between countries, but certain trends can be seen. The potential added value from applying saline agriculture and current costs borne due to salinization are relatively similar, ranging between 200 and 650 USD per hectare. Most of the past studies have focused on the high costs induced by salinity, including loss of yield, additional soil treatment costs and forgone opportunity costs. However, the evidence from the research included in the meta-analysis suggests that profits can be obtained thanks to the cultivation of salt-tolerant crops. Finally, potential revenues can be calculated based on average yields and prices.

Further research should focus on the costs of saline agriculture application beyond trials and pilots. To get more insight into projects' feasibility and profitability, we recommend collecting more precise financial data on fixed and variable costs, and benefits, including non-direct values. These could be obtained through a survey among the stakeholders to assess social and environmental costs and benefits, as well as the willingness to pay for the necessary investments, saline agriculture's products or accept the changing environment.

Since the potential of salt-tolerant crops cultivation seems evident, it is important to enumerate reasons why it is not yet widespread. These include a lack of knowledge and understanding of soil and water management methods, varying costs and conditions among the countries, lack of focus on salt-tolerant varieties among the breeders, difficulties with knowledge transfer to farmers living in remote areas, and the lack of financing for initial saline agriculture investments. The means to overcome these obstacles should be explored in future studies.

The results of this research project offer one of the first estimates of economic potential that could be useful for various groups of stakeholders. For policymakers, it shows that the cultivation of salt-tolerant crops can be part of the answer to food security issues at a local, regional and global scale. The use of saline degraded soils allows for the cultivation of previously empty lands and may help to prevent land-use change in other areas, which may have higher biodiversity or provide other ecosystem services. Saline agriculture may be also a way to diversify the farmers' portfolio, innovate and obtain additional financial resources.

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