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# Using an Agroecosystem Services Approach to Assess Tillage Methods: A Case Study in the Shikma Region

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**Abstract:** The use of ecosystem services (ES) in agricultural management is expanding; however, its integration in decision making processes is still challenging. This project was formulated to examine the ES approach and its usefulness with regard to management dilemmas. The Shikma region, north of the Negev Desert, was chosen as a case study. The management issue identified was the effect of various alternatives (minimum-tillage, no-tillage, straw-mulch and stubble-grazing) on the supply of ES. The expert-based ES assessments' findings reveal that no-tillage has the potential to increase many agroecosystem services and be more profitable for the farmer and the public. However, trade-offs between different ES and among stakeholder groups make it difficult to reach an unequivocal conclusion. As we have found, the process of the study is as important as the results. Throughout the project, an effort was made to engage stakeholders and policy-makers and to define decision-making processes. The study suggests that the ES approach can be useful in expanding the scope of agricultural management beyond provisioning services and create collaborations among farmers, communities, national institutions and environmental organizations to advance conservation agriculture. The study provides guidelines for conducting a productive ES assessment process that will lead to enhanced awareness and implementation.

**Keywords:** no-tillage; soil erosion; ecosystem services; conservation tillage; multi-stakeholder analysis; straw mulch; stubble grazing; Negev Desert

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## 1. Introduction

### *1.1. Agroecosystems*

Agricultural ecosystems provide humans with food and forage, bio-energy and pharmaceuticals and are essential to human wellbeing. These systems also produce and influence a variety of Ecosystem Services (ES), such as regulation of soil and water quality, carbon sequestration, support for biodiversity and cultural services. Depending on management practices, agriculture may have a negative impact on these services and cause soil erosion, loss of wildlife habitat, nutrient runoff, sedimentation of waterways, greenhouse gas emissions, and an increase in pest and weed contamination [1]. These may ultimately undermine the natural base upon which agricultural livelihoods depend [2]. Research on agroecosystem services examines the trade-offs that may occur between provisioning services and other ecosystem services. As more effective methods for assessing and valuing ES become available, the potential for "win-win" scenarios increases. Under all scenarios, appropriate agricultural management practices are critical to realizing the benefits of ES and reducing the negative effects resulting from agricultural activities [1]. Agroecosystem services are defined as the contributions of ecosystem structure and function combined with other inputs, to human well-being "Salzau message" 2010 in [3]. "Other/additional inputs" refer to non-ecosystem-based anthropogenic contributions to ES, for example fertilizers, energy, pesticides, techniques, labor or knowledge use in human-influenced land use systems. A balanced assessment of ES provided by agriculture requires a systems-level socio-ecological understanding of related management practices at local to landscape scales [4].

### *1.2. Development of Conservation Tillage*

The transition from the plow to various forms of conservation tillage began after World War II with the attempt to find ways to produce more crops while using less energy and with the development of non-selective herbicides which made the transition possible [5–7]. Only in the 1990s the concept of no-tillage as a method for soil and water conservation evolved as it became related to the network of ecological endeavor. In addition, at that time, farmer associations for no-tillage and soil conservation were forming, and governments began to support it. Research shows that the process of no-tillage development and uptake may be regarded as a dynamic process of co-creation of innovation including human actors (pioneering farmers, extension workers, scientists, government officials) and non-human actors (herbicides, no-till machinery, policy incentives, soil conditions, crops and yield) [6–8]. By 2010, no-till was practiced on about 111 million hectares globally, an annual growth rate of 6 million ha in many kinds of climates, soils and cropping conditions [9]. A review of conservation agriculture and ES shows that no-till technologies are known to be very effective [5,10] and the awareness of their advantages is growing. Nevertheless, many farmers still struggle with no-tillage adoption [8] and the body of research on constraints regarding its adoption is continuously growing [11–14].

In Israel, the development and spread of no-tillage began in the 1990s. Long-term experiments began in the Negev Desert to reduce energy expenditure and expenses. In the beginning of the millennium, no-tillage was implemented on a number of farms in the Jezreel Valley in northern Israel. In 2007, the Ministry of Agriculture took an important step and began providing annual monetary support for managing fields with soil and water conservation tillage regimes, and provided a 40% subsidy for no-tillage machinery [15]. The long-term experiments showed that no-tillage, including no-tillage with straw mulch, has the potential to increase many agroecosystem services while being economically viable for the farmer. Therefore, it was recommended that no-till farming should be implemented in the dryland fields of Israel [16,17]). Nevertheless, implementation of no-till is still relatively low among Israeli farmers [18].

### *1.3. Using the Ecosystem Services Approach*

Understanding the impacts, of actual and potential changes at a site on ES is important for promoting better planning and management decisions to support ES delivery. The approach emphasizes the importance of comparing estimates for alternative states of a site (for example, before and after conservation agriculture) so that decision-makers can assess the net consequences of such a change, and hence the benefits for human well-being that may be lost through the change or gained by conservation [19]. The ES approach is becoming a dominant part of environmental discourse as well as of the academic literature [20]. The supporters of the approach emphasize its advantages in creating a common language between various stakeholders and decision-makers based on a common basis of data, assessments and preferences. However, in fact, a large part of the work in this field is academic, and it is often difficult to show an explicit impact on decision-making [21]. Only in a relatively small number of ES assessments is a profound process carried out that includes defining the need of the stakeholders on the site, involving the public, conducting ES assessments, and creating a participative discussion on the findings that will influence decision-makers in managing natural resources and landscapes more sustainably.

In this study, we present an example of how to conduct a cooperative process to incorporate the ES approach in agroecosystem management, and how the process and its outcomes can facilitate the enhancement of the overall ES supply for sustainable agriculture. The framework for the project was established jointly by OLI (the Open Landscape Institute) with the Shikma Park executive committee. The sustainable and participatory approach of the Shikma Park management program, where the study takes place, and the remarkable collaboration of the farmers and stakeholders in the area, provided an excellent environment for this study. The goals and focal points are: (1) to assess the effect of different tillage methods used in the dryland fields of Shikma Park, on agroecosystem services; (2) to involve farmers, stakeholders, government officials, experts and the public during the study process and following it, while creating dialogue, raising awareness, obtaining feedback and promoting the implementation of findings; (3) to influence policy and suggest appropriate institutions that can provide effective incentives to promote cropland management that enhances agroecosystem services.

## 2. The Study Region

Shikma Park is a geographical-organizational unit, composed of various types of open landscapes: agricultural fields, protected areas (at varying levels), and rural communities. It is similar to a “biosphere reserve” in its conservation and sustainable management approach without officially being one (see biosphere reserves in [22]. It is located in the semi-arid northwestern part of the Negev Desert in Israel (Figure 1). A significant part of the area is agricultural: 25,000 hectares of agricultural land, of which 40% is dryland agriculture, including fields that are alternately rain-fed and irrigated. The average annual precipitation varies between 200–400 mm**.** Wheat is the crop grown on most of the dryland areas in Israel [23] as well as in the dryland fields of Shikma Park, with rotations of barley and various legume types. Several tillage methods are used, including conservation tillage of various types, levels and distribution throughout the farmers' fields. Over the past few years, awareness of conservation agriculture in the northern Negev has increased, leading some of the farmers to modify their management practices and use reduced tillage (minimal, non-inversion tillage), and others to use no-tillage (zero-tillage) [24]. In Shikma Park most of the dryland fields are under reduced-till regimes, while others, about 25%, are under no-till regimes (some of the fields under no-till regimes combine occasional tillage every 4–5 years). Due to well acknowledged benefits of no-till systems [5,10], we attempted to understand, by using the ES approach, why there are still farmers who do not adopt no-till regimes.

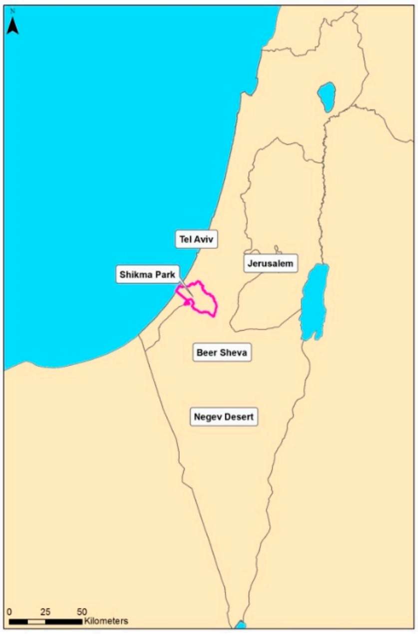


**Figure 1.** Shikma Park.

## 3. Materials and Methods

The methods were developed during the project process according to the goals described above. It was aided by ES guidance manuals prepared by various international ES working groups such as: [19,25–27], combined with specific features compatible to the socio-political framework in Israel and Shikma Park. The preliminary steps were selecting the research site and creating the organizational structure of the project. Shikma Park was chosen due to the sustainable and collaborative approach of its management program and past collaboration between OLI and the Regional Executive Committee. A partnership was created with the Shikma Park management members, farmers and other stakeholders and experts from local and national levels. In addition, two committees were formed to support and escort the project: a steering committee, to provide feedback and approve the project after every stage, and a multi-disciplinary professional committee of experts—to help with professional ES assessments. Economists were added to the working group for conducting the economic assessment. The early engagement of stakeholders and decision-makers is a key component of an assessment, as it can help provide an accurate understanding on the economic, ecological, social and cultural dynamics of the site [28]. The means used to strengthen stakeholders' engagement included meetings in different forums, interviews, discussion groups, mutual fact-finding, steering committees, agricultural and environmental conferences and day-excursions to the fields. The project includes the following stages. The stages described can be used as guidelines for conducting a productive ES assessment process.

(1) **Defining agroecosystem management issues** currently on the agenda at the research site and **identifying management alternatives**. We began, as do most ecosystem assessments, with extensive consultations with stakeholders and specific user groups in Shikma Park to identify priorities for the assessment questions. These consultations are fundamental to both the relevance and the legitimacy of the process and play a key role in providing its structure and focus [29]. Following the consultations above, the management question and alternatives were identified.
(2) **Mapping stakeholders, policy makers and decision making processes** related to the alternatives identified, based on interviews with stakeholders, reports and literature.
(3) **The perspective of farmers and experts regarding the constraints to no-till adoption.** As part of the study, we conducted open-ended interviews with farmers and experts in order to get their views on what prevents wider adoption of no-tillage in light of findings that demonstrate the success of the method. Insights into farmers' decision-making together with barriers/drivers for implementation of sustainable soil management practices, can contribute to a better understanding of what is needed to foster better compatibility between the method and specific farms, and thus encourage adoption of these practices[14]. All farmers that cultivate land in Shikma Park (six farmers), four agricultural extension service instructors that work or worked in the past in the area, the head of the agricultural organization of the area, as well as several experts from the R&D, the Faculty of Agriculture and the Ministry of Agriculture were interviewed. All interviewees were asked about the constraints as well as about specific issues that relate to each expert that were necessary for the different stages of the project.
(4) **Preparing for ecosystem services assessment of each management alternative identified**. This stage included screening and prioritizing relevant ES and recruiting experts/professional working groups for the assessment. The first part was done by identifying ES relevant to the alternatives being assessed, from the broad list of ES that was formulated by the Israel National Ecosystem Assessment according to international ES work [27,30,31]. Then these ES were prioritized according to various parameters and indices including: relevance and importance to the site, existing tools or data for evaluation, level of complexity and resources needed, and the feasibility of assessment. The second part, of recruiting experts for the assessment, was done by using the "snowball effect" often used in qualitative social research: we began by identifying a preliminary list of experts to consult with on each of the services, these experts provided us with names of additional experts recommended by them, and those provided us with additional experts and so on. In this manner, we were able to reach a wide network of experts in each subject. In some cases, such as the assessment of soil erosion, a larger group of experts was formed to help and guide the assessment process. ES that were ranked high later underwent an in-depth professional assessment by the experts.
(5) **Conducting the ecosystem services assessment.** The assessment process was based on collection of existing data (from the literature and reports), interviews with stakeholders and experts, extrapolation from data collected in other locations, and when needed, a new interpretation of the data gathered on-site, or a small-scale scientific study. For example, a survey was held in order to identify the public's perspectives regarding their environment and their perceptions regarding the

transition to no-tillage (the survey will be elaborated in the following stage). The services were assessed quantitatively, qualitatively, socially, and economically where possible. The economic assessment was based on data gathered from the expert-based ES assessment reports, the farmers, agricultural reports and previous economic evaluations done for the Shikma-Besor Drainage Authority. It was done by using the accepted environmental economic methods including: evaluation of externalities, avoided damage cost, damage prevention cost and cost-benefit analysis. Each expert provided a detailed report of the service being assessed, describing the service and how it is affected by the different alternatives identified, and indicating the trend (increase or decrease of the service) and the level of confidence according to his/her professional opinion. The report was written according to an outline provided to them. Subsequently, the assessments were summarized and presented in a table (Table 2). In the scope of this paper, only the summarized assessments are presented. The final part of the assessment process was presenting the assessments to the relevant group of stakeholders and experts, receiving feedback and suggestions, and revising and implementing them where possible.

(6) **Conducting a public survey of the perceptions of the Shikma Park residents** regarding their environment, agriculture and conservation tillage. The goals of the survey were: to assess the public's attitudes towards agriculture and the environment, to raise local public awareness to ES and environmental issues, to expand and intensify the existing educational program, create community participation, and to assess cultural ES that would be difficult to assess otherwise. The survey was held as part of an educational program led by the regional Nature and Parks Authority and in cooperation with it. The survey included 246 respondents from the Shikma Park local communities and nearby towns. One of the questions asked in the survey was formulated to understand where the stakeholders stand regarding the transition to conservation tillage and who should pay for it.

(7) **Integrating & communicating the results**. In this stage the main findings (from all the stages above) were integrated in order to communicate the results to decision makers in a simple and coherent manner and provide them with an effective tool, while being transparent about the limitations and gaps of the findings. This was done by using tables and charts to simplify and focus the findings, while emphasizing the multi-stakeholder influence. The tools chosen for presenting the findings were *rose plots* and the *table of distribution of benefits among stakeholders* that were obtained from previous ES work done by [19,25]. Another important part was advising decision makers on mechanisms and research topics that need further investigation that can be used to facilitate the implementation of conservation tillage. This part will be described in the discussion Section.

## 4. Results

This section presents the outcomes of each stage described in the materials and methods section above.

### *4.1. Defining the Agroecosystem Management Question and Identifying Alternatives*

The management question that was chosen was: "the effect of various tillage methods used in the dryland fields of Shikma Park on agroecosystem services". The following tillage alternatives were identified:

(1) Minimum-tillage—In this area, it refers to shallow plowing once a year; deep plowing is seldom used.
(2) Conservation-tillage—No-tillage including long-term no-tillage (12 years) and occasional tillage (shallow plowing or deep plowing every 4–5 years).

Additional alternatives include crop residues/straw mulch alternatives:

(1) Baling and selling of wheat straw (leaving 5–15 cm stubble)—Currently all fields fall under this category.
(2) Leaving straw mulch as ground cover (3,000 kg per ha, at least 30–40 cm high) as is customary in most no-till fields around the world and as was recommended in a long-term no-tillage study done nearby [16,17].

Crop residue management is another important topic in conservation agriculture. It involves maintaining a permanent organic soil cover by leaving the previous year's residue on the field. In general, crop residue on the soil helps maintain humidity and promote soil microbial activity, while increasing the organic carbon influx on the ground and improving the structure and quality of the soil. Straw cover protects the soil from raindrops and minimizes evaporation and the risk of runoff and soil erosion [16,17,24,32,33].

An additional alternative is stubble grazing by sheep in post-harvest wheat fields:

(1) Permit sheep stubble grazing in post-harvest fields
(2) Prevent sheep stubble grazing in post-harvest fields

Stubble grazing by livestock in post-harvest wheat fields is a common practice throughout the Middle Eastern dryland fields, including the Negev Desert where this study was conducted. Between June and September, livestock enters the post-harvest fields after grazing in other open landscapes and JNF (Jewish National Fund) forests from February to May. Wheat fields are another source of grazing land that compensates for the decreasing amount of pasture over the years. The Bedouin shepherds in the area have been grazing their sheep on the wheat fields for dozens of years. Some farmers continue with stubble grazing on their fields while others have stopped. The growing awareness of conservation agriculture that is leading to modifications of management practices by using no-till and crop residue methods, is threatening the practice of post-harvest stubble grazing [24].

The alternatives above are dealt with in the text separately and combined where needed. For example, leaving straw mulch in the field and stubble grazing cannot be combined, but no tillage can be combined with straw mulch or without.

### *4.2. Mapping Stakeholders and Decision-Making Processes*

Table 1 shows the main stakeholders that were identified, whose decisions may have a direct impact on the choice between the management alternatives described above. The mapping of these stakeholders was conducted to identify the decision-makers whose engagement in the process is crucial.

**Table 1.** Mapping decision makers and their point of decision.

| Decision Maker | Decision Issue | Interest/Perspective |
|---|---|---|
| Ministry of Finance | Budget allocated for conservation tillage | Internalization of externalities |
| Israel Land Authority | Land leasing regime and terms | Securing the value of the land |
| Ministry of Agriculture | Extent and type of incentive/subsidy programs for soil conservation | Agricultural sustainability and profitability |
| Drainage and River Authority | Drainage basin master-plan<br>Organizational support for soil conservation | Regulation of soil erosion, water runoff, river sediments |
| Shikma Park Executive Committee | Representation of farmers vis-à-vis the institutions | Sustainability, economic profit, conservation |
| JNF Forest Managers | Part of the committee that regulates grazing in the park | Grazing in the forests and their vicinity as a tool to prevent wildfires and conserve soil |
| Farmers | Selecting the tillage method to implement, request for government support, permit grazing | Economic profit, long term sustainability |
| Shepherd | Remain in permanent dwellings or move with the herd to graze in agricultural and forest areas | Feed for their sheep, economic profit, preserving their pastoral lifestyle |

### *4.3. Farmers' and Experts' Perspectives on the Constraints to No-Till Adoption*

Below are the main constraints that were identified in the interviews. It is interesting to note that most of the constraints that were mentioned by the farmers and the agricultural extension instructors were also mentioned by the Ministry of Agriculture experts, Research and Development stations and faculty of Agriculture; therefore, we did not separate the constraints according to the specific stakeholders that mentioned them.

- High cost of equipment—government subsidies are insufficient and the machinery is difficult to maintain; once broken it is hard to fix.
- There is a lack of scientific experiments and research on the method and what does exist is often dubious due to small sample size and the different soils and topographic conditions of the plots.
- A research and development network and agricultural advice are lacking; a private network is partially replacing the previous government network.
- Some of the farmers are conservative and skeptical regarding the no-till approach.
- There is insufficient knowledge regarding weed and pest control resulting from no-tillage.
- Leaving straw mulch is problematic in Israel due to the high price received for selling it.
- Lack of strong evidence for economic profit from the transition.
- Lastly, an important driver of change was identified: as the water supply for agriculture from treated wastewater increases, potential land for no-till farming is decreasing, as more fields will be irrigated.

**Table 2.** The effect of the transition from minimum tillage to no-tillage on ecosystem services delivery based on experts' assessments.

| Ecosystem Services | Benefit of the Service | Trend: Direction and Strength (Increase or Decrease) | Level of Confidence | Description/Details | Main Sources, Experts and Professionals | On-Site Economic Assessment (Economic Team: Gadi Rozenthal and Hadar Fuchs-Rubel) |
|---|---|---|---|---|---|---|
| **Agricultural crops** | Food and animal feed | ↑ | Medium | According to experts and farmers in the area: better crop yields in no-till farming combined with straw mulch. According to others: there is no certain increase in crop yields but economic profit is not negatively affected. | [16–18,34]; Farmers and economic team. | The farmer is likely to enjoy an increment of 20 NIS*/dunam**/year for the amount and quality of the crops and 6 NIS/dunam/year for the straw. |
| **Soil carbon sequestration greenhouse gas regulation** | Climate regulation | ↑ | Low | Preventing soil erosion increases gas exchange in the soil. In addition, no-till saves energy from machinery and consequently reduces emissions. However, on-site calculations show that since the no-till fields use additional chemical fertilizers and herbicides it is hard to specify an increase in climate regulation in the short term. | Team leaders: Yoni Weitz and Dr. Jose Gruenzweig. [33,35,36]. | Fossil fuel consumption decrease of 2.5 liter/dunam/year equivalent to 5.9 kg/dunam/year. Value of decrease in $CO_2$ emission equivalent to 0.65 NIS/dunam/year in case of no chemical fertilizer addition. |
| **Water cycle Regulation** | Soil moisture retention | ↑ | High | Decrease of runoff, water percolation in soil, additional water available for plant uptake. | [16,17] | Higher yield from crops due to additional water available for the plant. The public benefit is 4 NIS/dunam/year. |
| **Disease and pest regulation** | Plant pest and disease outbreak regulation | ↓ | High | Increase in rodent activity and a minor and unstable effect on insects, pests and diseases. Increase in uncertainty regarding crops due to lack of knowledge and guidance on the subject. | Team leader: Ofer Mendelson. [37,38]. | Increment of 6.7 NIS/dunam/year for pesticides. |
| **Alien or invasive species regulation** | Weed regulation | ↓ | High | Increase in weed range, subsequently regulated by additional herbicides, which lead to higher costs and the risk of developing herbicide resistance. Increase in uncertainty regarding crops due to lack of knowledge and guidance on the subject. | Team leader: Ofer Mendelson in consultation with Prof. Baruch Rubin, Local farmers and extension instructor Uzi Naftaliahu. | Increment of 4 NIS/dunam/year for herbicides (not including future risk of herbicide resistance, which will create additional costs). |
| **Soil erosion regulation** | Maintaining soil quality and quantity, and regulation of wind erosion | ↑ | High | Global research and experiments in the Negev Desert show an explicit trend of soil erosion prevention in no-tillage systems. On-site assessment of soil erosion risk under "business as usual" scenario shows: between 0.15-0.61 ml/year. However, according to experts' feedback: it could reach between 1-2 ml/year or even 4. | Team leader: Alon Yaron. [9,10,16,17]. | 1,341 NIS/dunam/year can be saved by preventing erosion [39,40]. |
| **Symbolic interactions with the ecosystem** | Cultural identity | ↓ | Low | A threat to the farmer's identity as a ploughman and to the Bedouins' identity as pastoralists grazing their sheep for many generations. | Interviews with local farmers, shepherds and experts. [41,42]. | - |
| **Symbolic interactions with the ecosystem** | Heritage and sustainability values | ↑ | High | Strong cultural links between local residents and agriculture. Conservation tillage allows protection of soil and agriculture for future generations. | Survey: "Local residents' perceptions of the environment in Shikma Park". | - |
| **Biodiversity and habitat** | Improvement of biodiversity status | ↑ | High | Improvement in: species richness and diversity, amount of organic matter in soil, intensity of biological activity in soil and landscape complexity. May also have a negative effect because of additional use of pesticides and herbicides. | Dr. Amir Perelberg; [9,10]. | - |

*NIS—New Israeli Shekel; **1 dunam equals 0.1 hectares.

### *4.4. Preparing for the Ecosystem Services Assessment*

In this stage we screened and prioritized relevant ES according to the methodology described in the section above. Nine services were selected for assessment (see Table 2). In order to conduct the assessment, a team of experts in the various fields, were recruited. These included economists, geomorphologists, Ministry of Agriculture experts, agricultural extension service instructors, drainage authority officials, ecologist, grazing experts, social study experts, *etc.* Each expert led the assessment of the ES related to his/her field.

### *4.5. Conducting ES Assessments*

ES assessments are used to compare alternative states of the site under different management systems in order to eventually help decision-makers identify what could be the most plausible state of the site [28]. Table 2 shows the increase or decrease in the various ES with the transition from minimum tillage to no-tillage as well as the confidence level (low, medium, high), main sources and experts, description of the effect and the on-site economic assessment. The assessments were done by the recruited experts mentioned in the previous stage, based on existing data (academic literature and local reports), stakeholder and expert interviews, field excursions, public survey, expert forums, and economic evaluation where possible.

It should be noted that ES assessments were also conducted for the two other alternatives described above: leaving straw mulch cover *versus* removing it and permitting stubble grazing in post-harvested fields *versus* preventing it. In the scope of this paper, these will be presented only in short in rose plots (Figures 3 and 4) and in Table 3.

### *4.6. Educational Program and Public Survey: Residents' Views on the Environment in Shikma Park*

Another part of the assessment process was a survey of public perceptions of the environment and agriculture. Numerous scholars have emphasized that understanding how humans perceive and value ES is as fundamental to ecosystem management as understanding how ecological functions generate these services, and is a crucial step toward successfully integrating the ES concept in policy [43–45]. The results of over 70% of the respondents show that the local residents value the open landscape and its aesthetic, environmental and cultural significance and use it for recreation and tourism. They appreciate the agricultural fields and their significance for food production, water infiltration, protection of open landscapes from development and as part of the residents' identity and connection to the landscape. Regarding the question who should pay for the transition to conservation tillage: about 80% were found to be willing to adopt conservation methods and 11% to do so even at their own expense. It is important to mention that most of the residents in the area live in kibbutzim, collective communities that combine socialist and Zionist values; therefore, the whole community is affected by the profit and loss from agricultural activity.

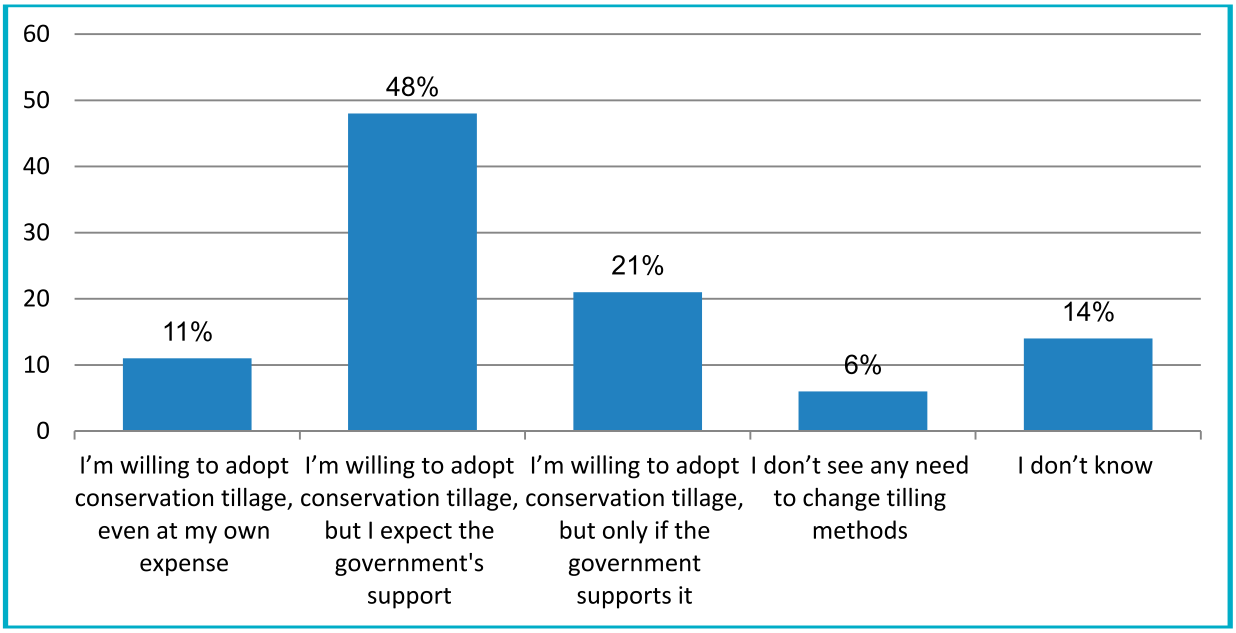


**Figure 2.** The perspectives of the public regarding the adoption of conservation tillage and who should pay for it.

### *4.7. Integrating & Communicating the Results*

After completing individual assessments of the effect of each alternative state on overall ES, an integrated assessment was prepared in rose plots (Figures 3 and 4) and Table 3 based on the assessment of the experts shown in Table 2. Figure 3 presents the impact of "no-tillage without straw" and "no-tillage with straw" on ES delivery in reference to the existing most common management—minimum-tillage. Figure 4 shows the impact of the transition between grazing alternatives on ES delivery. The scale of the measurement includes 5 levels of impact on ES, while in the reference management all ES received level 3. The impact of each management alternative on each ES is measured according to the reference alternative: an ES that increased received the value 4 or 5 (depending on the degree of increase); an ES that decreased received 1 or 2; and ES that remained unchanged received 3.

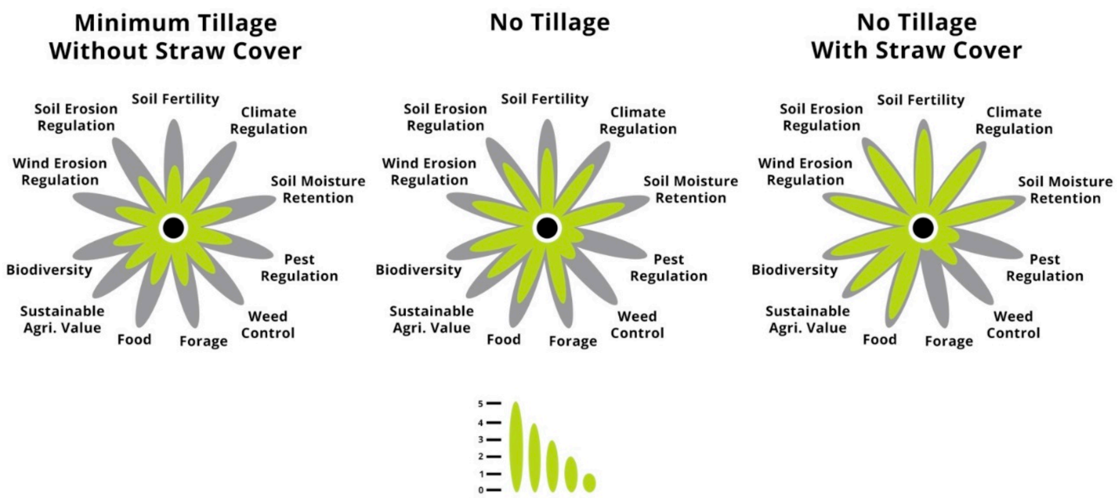


**Figure 3.** Rose plots showing a comparison of the impact on ecosystem service delivery of no-tillage alternatives in reference to minimum tillage, based on experts' ES assessments.

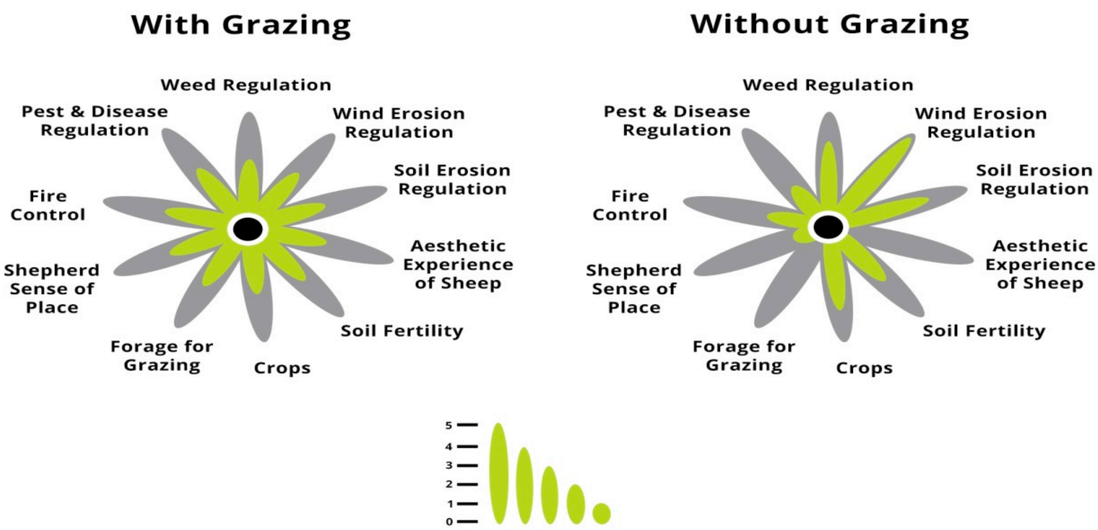


**Figure 4.** Rose plots showing a comparison of the impact on ecosystem service delivery of "without grazing alternative" in reference to "with grazing alternative", based on experts' ES assessments.

**Table 3.** Distribution of benefits among stakeholders.

| Decision | Goal | Winners | ES decreased | Losers |
|---|---|---|---|---|
| **Increasing one service at the expense of other services** | | | | |
| **Straw mulch** | Maintain humidity and promote soil microbial activity, while increasing the organic carbon influx on the ground and improving the structure and quality of the soil. Increasing crop quantity and quality. | **The public and the state:** Soil conservation for future generations. **The farmers:** Extended soil moisture retention in the growing season, particularly useful in drought years. Soil conservation for future generations. | Provision of animal feed | **Farmers:** Economic loss due to not selling the straw, which is very profitable in Israel. **Consumers**: May need to import straw or buy from another area in Israel. **Milk consumers:** May be negatively affected by the price increase because of high straw import prices. |
| **<u>Competition among different users for limited services</u>** **The decision to prevent stubble grazing creates additional winners and losers.** | | | | |
| **Preventing stubble grazing** | To enable straw mulch cover that improves soil and water conservation. To prevent the potential damages caused by unregulated grazing such as: soil quality degradation, water runoff and introduction of noxious weeds via the sheep's wool and droppings. To prevent potential disputes between shepherds and farmers. | **Farmers:** Improving weed control, preventing soil erosion. Preventing the possibility of negative relationships with shepherds (some farmers complained of this). **The state and the public**: soil conservation for future generations. | The service of feed for grazing will no longer be available, cultural services such as shepherd identity, heritage and sense of place are harmed, pest and disease regulation, fire control, and sheep as an aesthetic function in the landscape. | **Shepherds:** Lack of grazing lands, additional cost of buying feed instead of grazing. The effect on their Bedouin-pastoral lifestyle, identity and tradition of many years. **Farmers**: Loss in income from rent paid by shepherds. **Foresters:** might cause a negative effect on fire control in forests due to the combined system of grazing in forests prior to grazing in the wheat fields. Without stubble grazing the shepherds may stop forest-grazing as well. **Public:** Lack of sheep in the agricultural landscape may affect the scenery and the anemone bloom. |

An important component, which is not expressed in the rose plots, is the multiple stakeholders that are affected by the management dilemma, which makes the question of who is harmed and who benefits from the increase and decrease of each ES very important. The multi-stakeholder approach aims to identify all the groups of people affected by the current state of a piece of land and its future use [26]. In order to provide decision-makers with the information on how various stakeholders will be affected by the transition, and the time span of the impact (short *versus* long-term), the following table was prepared (based on [46], p. 40 and [25], p.60):

## 5. Discussion

The expert-based ES assessments indicate an improvement in most ES with the transition to no-till, and a further improvement with straw mulch as is seen in Figure 3. The main trade-off to be considered with the transition to no-till is the advantage of soil and water retention (a service that is expressed in the long-term protection of land for future generations) *versus* the main disadvantages: a reduction in weed and pest control and loss of profit from selling the straw. The reduction of weed and pest control may cause a series of events: additional use of herbicides and pesticides, which imply a possible development of herbicide-resistant weeds and pesticide-resistant pests that may cause additional damage to crops, economic loss for the farmer, and further harm to the environment and ES in surrounding ecosystems.

The decision of the farmer to prevent stubble grazing is one of the outcomes of leaving straw mulch, but the decision can be made based on other considerations, regardless of whether the farmer decides to leave mulch or not. Figure 4 and Table 3 show that four of the services increase without grazing (regulation of soil erosion by water and wind, weed control and crops) and five of them decrease (forage for grazing, fire control, the shepherd's sense of place, aesthetic view of sheep as part of the landscape and pest control). In addition, one ES remained unchanged—quality of soil. This is explained by the fact that the soil is under conflicting impact—on the one hand, the sheep enrich the soil with their droppings but on the other hand, their trampling may increase soil erosion. Table 3 shows that when shifting to no-tillage with straw mulch the farmers and the state & public are the main "winners". This agrees with the results of the cost-benefit analysis that shows that over the long-term, it is advantageous for the farmer and society as a whole to make the transition, and with the public survey results that shows public support for the transition. The main "losers" are the shepherds that would not be able to graze and the farmers who, in the short-term, will not profit from leasing the land to the shepherds, nor from selling straw. It is important to note that in interviews with shepherds and experts, continuation of grazing was questioned unrelated to the issue of straw mulch, but because the younger generation might not want to maintain the shepherd lifestyle. In addition, Bedouin grazing on Jewish farms is also affected by political forces beyond the scope of the farmer's decision. There are also additional "losers" such as straw consumers, who may need to import straw, as Shikma Park produces a large part of the straw in Israel. This in turn, may affect milk consumers by raising the price of milk. Therefore, there are obviously no clear-cut answers. It can only be stated, that according to current prices, the economic assessment shows that in the short term it may be more advantageous to keep on selling the straw.

In order to deal with the issues raised above, a few possible mechanisms have been identified, that may help to enhance overall ES supply and be more suitable to the region and the stakeholders, with further investigation. Examples include occasional tillage (as recommended by the Ministry of Agriculture) which would contribute to pest and weed control and allow application of organic fertilizers in the soil. In addition, practicing IPM (integrated pest management) could further assist pest and weed regulation in a manner less harmful to the environment. Partial straw cover—leaving a cover of straw only about 10–15 cm high (as opposed to 30 cm or more), as is done on several fields today—will allow farmers to continue selling straw and still enjoy some of the benefits of straw mulch. In terms of moderate grazing, in cases when grazing continues, farmers should be aware of the mode of grazing (amount of sheep per hectare and post-fleece introduction of the goats) to minimize its negative effects [24,42,47]. In an attempt to find ways to ease the economic barriers for the farmers, or mitigate the fear of unstable income, the following mechanism was proposed: instead of financial support (grants for purchasing necessary equipment) as the case is today, an insurance plan for agricultural hazards and risks that may result from the transition to no-tillage would be formulated. These mechanisms were presented to various key policy makers in the Ministry of Agriculture (including the Division of Research, Finance and Strategy), who gave a positive feedback, and agreed to examine the issue further. During the study, a list of topics that need further examination was identified and communicated to governmental and academic research institutions. Several conservation tillage studies on the topics identified such as soil degradation risk assessment, farmer constraints in adopting no-tillage, solutions for weed and pest control and the effect on biodiversity have already begun in different parts of the country. The studies include either farmers, extension workers or ministry of agriculture representatives in the teams in order to improve the future implementation of the results [6–8].

One of the main challenges in the course of the study was the agroecosystem services assessment process. This was due to the following reasons: lack of detailed and organized documentation by the farmers regarding inputs and outputs of different tillage systems, variation in physical conditions among the farms being studied, as well as economic and social conditions, biased information provided by different stakeholders and experts to promote their agenda, limited scientific research done in the region, difficulties in the implementation of research conclusions from other places in the world because of different physical conditions and scale, difficulty in quantifying the findings without a large scale-long-term scientific research and lack of economic tools for providing value for un-marketed goods. These challenges were partly dealt with by providing the best assessments possible under the existing limitations, *i.e.*, in some cases only the main trends and insights were reported, and also by making complementary on-site research efforts, conducting economic assessments and convening expert forums. For example, in the assessment of soil erosion regulation, which is a crucial issue in this context, assessing the damage caused by erosion under the "business as usual" scenario and the benefit in regulating it was difficult; therefore, specific expert forums were convened to advise on the issue.

## 6. Conclusions

This study proposes a few guidelines for conducting a productive ecosystem services assessment process that will lead to enhanced awareness and implementation of policies that will enhance ES supply. During the project, the complex system of conservation tillage decision making and its effect on ES was studied and documented. As we have seen, the process is as important as the results. We believe that providing an unequivocal answer regarding which of the alternatives is preferable should not be the ultimate goal of the ES process. Rather, it should be to provide decision-makers with findings that could help them make better decisions, which would consider benefits to the environment and the stakeholders involved and to raise public awareness of ES and the risks involved in their degradation. The research shows that by conducting a participatory assessment process with a wide range of stakeholders and experts, conducting a multi-stakeholder analysis, involving the public through interviews, a public survey, meetings and an educational program, *etc.*, and communicating the results to policy makers, these goals can be met. Further outcomes of the study showed that the process and its deliberations enriched and deepened the agroecosystem management discourse and contributed to expanding the scope beyond provisioning services (crops and feed) to soil regulation (and the risks of soil erosion) as well as to other services such as carbon sequestration, biodiversity, water cycle regulation, pest and weed control, cultural services and sustainability values. The study emphasizes the potential of the ES approach to create collaborations between farmers, regional councils, environmental organizations and policy makers (such as the Ministry of Agriculture and Drainage Authority) to promote the initiation of effective research and policies which will maximize the overall ES supply and benefit all. We believe that the network of people working for the implementation of conservation tillage and soil conservation has been expanded and unified through this study. We hope that the seed has been planted for further promotion of conservation tillage implementation and further use of the ES approach in agroecosystems.

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## Author Contributions

Uri Ramon, together with the head of the Open Landscape Institute had the original idea for the initiation of the project and led the development of the project and the methodology. Hila sagie coordinated the project, led the public survey, and the preparation of the manuscript. All authors participated in the writing and revision of the manuscript. In addition, all authors approved the final manuscript.

## Conflicts of Interest

The authors declare no conflict of interest.

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