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Soil related environmental considerations of farmers in the Great Hungarian Plain

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Abstract: Climate change and associated environmental changes are the major sustainability challenges facing the world today. The selection of appropriate agrotechnological elements is required not only to increase the quality and quantity of food produced but as well as reducing the costs of the farmers and protecting the environment for future generations. In the Great Hungarian Plain, the adoption of recent environmentally friendly technologies is still not sufficient and the region faces various environmental challenges. This study aimed to analyse the economic and environmental consciousness of farmers in the selection of 3 agrotechnological elements (soil protective cultivation, soil reclamation/conditioning, manure application). A pilot study was conducted on 5 representative farmers, in which they were interviewed, and questionnaires were designed to critically analyse farmers' perceptions of the environment based on the opinions of 106 respondents. The result show that farmers are aware of the environmental impacts of selected technologies in their farms. They highlighted some of the environmental challenges they are experiencing including drought, secondary salinization, and unfavourable soil properties. However, they showed more economic than environmental consciousness, as they suggested that it was important to be familiar with economic issues and conditions to ensure higher income. The level of willingness to introduce or apply soil protective cultivation, soil reclamation/conditioning, and manure differed from low to high.

Keywords: environmental consciousness, economic consciousness, reduced tillage, soil conditioning, soil reclamation

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Introduction

The world population is estimated to be 8 billion and is expected to increase to 9 billion soon, hence there is an urgency to increase crop yield to satisfy the world's growing demand for food (Looga et al., 2018). The major sustainability challenges the world is facing today are climate change and associated environmental changes (Abercrombie et al., 2020). With the recent face of climate change and the increase in the world's population, satisfying the needs of the population becomes a great challenge.

The natural resources used in food production are not enough to fulfil the growing demand for agricultural produce and products due to growth in population, urbanization, and increasing income. Maximum food production is also limited by the size of land available, selected agrotechnical methods and environmental challenges. The selection of appropriate agrotechnological elements is required not only to increase the quality and quantity of food produced but as well as reducing the costs to the farmers and protecting the environment for future generations. Agriculture's pivotal role in improving the world's economy, reducing poverty, contributing to food security, and rural development is important and cannot be ignored (Mwangi & Kariuki, 2015).

With the growing population, agriculture faces challenges of meeting the food demand of these populations, while attempting to minimize the environmental impacts of selected technologies (Robertson & Swinton, 2005). Knowledge on impacts of farmers selected technologies on the environment, could influence their perception of these technologies and influence their environmental behaviours (Ervin, 1982; Taylor & Miller, 1978). Agriculture has an impact on the environment and ecosystem as a whole (Kanianska, 2016), therefore the elements of agricultural technology such as continuous cropping, conventional tillage, monoculture, choice of nutritional supply to plants, irrigation etc. also involve environmental effects on their own. The major impacts on the environment and ecosystem that we face today as a result of these technologies include the decrease in productivity of the farmlands due to depletion of soil nutrients from runoff and greenhouse gas emissions (Schneider & Kumar, 2008). Thus, the future productivity of these farmlands and the environmental impacts of selected technologies depends on how we perceive the environmental and ecological elements of agricultural ecosystems.

Impacts of soil cultivation methods are visible on the physical, chemical and biological properties of the soil. Methods of soil cultivation include full and conservation tillage. Depending on the selected soil cultivation method each has consequences on the environment, for example, full tillage fractures the soil, disrupts the soil structure, soil temperature (Busari et al., 2015), accelerates the surface runoff and erosion, and releases CO_2 gas to the atmosphere (Lal et al., 2007). Whereas, conservation tillage involves practices that involve minimization of damage to the soil, conserves soil moisture and retain or prevent carbon emission to the atmosphere (Busari et al., 2015). It also reduces the leaching of nitrogen in the soil (Qi et al., 2019; Wang et al., 2020). Reduced tillage, zero tillage, mulching, ridge and contour tillage are some of the conservation cultivation practices. Zero tillage involves minimal disturbance of the soil to enhance soil biological activity, and maintenance of soil cover (crop residue) to reduce the impact on soil from raindrops or soil erosion. Reduced tillage involves the use of primary tillage to minimize the level of soil manipulation. Mulching involves methods of cultivation in which crop residues are left on the soil to supply nutrients to the soil, suppress weed growth and retain soil moisture. Ridge tillage involves the planting of crops along both sides or at the top of the ridges. Soil conservation practices are beneficial in reducing soil erosion, increasing soil productivity, reducing production costs. In soil conservation tillage practice, at least 30% of crop residue is left on the soil surface, this slows down the water movement, and as a result, it minimizes the amount of soil erosion. Additionally, conservation tillage has been found to have benefit predatory soil organisms that can enhance pest control by increasing the population of pest inhibiting organisms (Stinner & House, 1990).

In Hungary, the area cultivated under soil protective tillage is increasing year by year, though full tillage practice is still significant (30-40%) and it was the only soil cultivation method until the end of the 1990s (Birkás et al., 2021). Several measures were put in place to combat damages caused by drought and soil degradation, therefore, conservation tillage was introduced which aimed at reducing the depth of frequently cultivated soil layer and promotes topsoil formation which is rich in organic matter. By the early 2010s, conservation tillage was used on 35-50% of the croplands of Hungary de-

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pending if the season is dry or wet (Birkás et al., 2017). Reduced tillage is now the most dominant form of soil protective management that affects the soil stock in Hungary, however, crop residue management, irrigation management, and fertilizer management applying mineral fertilizers and organic amendments are other forms of soil protective practices that are being practiced in Hungary (Zsembeli et al., 2008).

The world population is growing which puts pressure on the agricultural land to meet the growing demand for agricultural food (Turmel et al., 2015), this has greatly affected soil fertility (FAO, 2017) and quality (Verhulst et al., 2010). For the soil to be healthy it has to be rich in soil organic matter content (SOM), therefore there is the necessity to do regular soil organic matter amendments which helps to improve the soil physical (soil structure, prevent soil erosion and runoff, soil compaction, improves soil temperature and moisture content), biological (soil biomass and diversity of soil organisms) and chemical properties (cation exchange, soil organic carbon, and soil pH) (Wilhelm et al., 1986, 2007) in return improves soil health, which is essential for yield improvement and at the same time it improves the productivity of livestock as well (Turmel et al., 2015).

Soil conditioning involves adding a product to the soil to improve the physical quality of the soil, fertility, and mechanics of the soil. According to research conducted in Karcag region, soil conditioning has a positive effect on agricultural soils as it facilitates vertical movement of the water, improves water holding capacity, increasesorganic matter content and facilitates leaching of excess salts from the root zone. Through the benefits of soil conditioning proven by various studies (Brandsma et al., 1999; Garcia et al., 2020; Zsembeli et al., 2019) soil conditioning can help improving the agricultural productivity of farming land (Kalra et al., 1998).

The main goal of our study was to gain information on what influence farmers in the selection of agrotechnological elements, whether they have more environmental or economic consciousness with special regards to the application of state of the art in soil cultivation, soil reclamation, and organic matter input. The data we collected can be used to encourage environmental awareness among farmers, the results contribute to an increase in quality of crop production, reduce costs and protect the environment for the future generation.

Materials and Methods

There were two sources of data and information involved in this study:

a) Questionnaire based on the TALA method,

b) Pilot study with the Advisory Board (AB) members of the Research Institute of Karcag (RIK)

TALA method

Jász-Nagykun-Szolnok (JNS) is a county in Hungary with many agricultural fields for large farm owners and hobby gardeners who have been practicing agriculture for over 300 years and they still face some challenges in adapting to climate change to optimize their field production capacity and maintenance of sustainable crop production. The adoption of recent environmental-friendly technologies is still low and the region faces various environmental challenges ranging from secondary salinization, methods of soil cultivation to fertilizers being used of which all have an impact on the environment. We elaborated a new technique of data collection called TALA method. TALA method is based on our idea that we should share useful information on the most up-to-date scientific results that can be used by the agricultural practice. TALA comes from the principle of Teaching by Asking and Learning by

Answering. The application of this method is not only to collect information from farmers but also involved a new and interesting way of knowledge transfer to the farmer. This technique worked in two ways, it enlightened the farmers on environmental issues which they may not have known about and at the same time collect data on their environmental and economic consciousness on agricultural technologies. The collected data helped to critically analyse the environmental and economic consciousness of farmers and to encourage the selection of appropriate agrotechnology when conducting farming activities. By use of this method, farmers are be more cooperative and give appropriate feedback, as information is not only taken from them but there is the transfer of knowledge to them. Based on the TALA method, a questionnaire was elaborated and sent to the farmers of JNS county by mail. The TALA questionnaire consisted of 5 topics of environmental issues including statements of the environmental and economic consciousness of the farmers and also the relevant questions on their plans if they want to apply them in the near future:

1. application of water preserving soil cultivation systems,
2. application of soil reclamation and/or soil conditioning,
3. application of manure and/or compost,
4. application of crop residue management,
5. application of region-specific crop varieties (land races).

In this paper, the first three topics out of the total five are discussed that are relevant to the pilot study topics with the AB members.

Application of water preserving soil cultivation systems

Environmental consciousness: According to the research achievements of RIK, land-use change from conventional to reduced tillage can save 200 kg soil organic carbon per hectare and 40 mm of soil moisture in the upper 30 cm depth of a typical soil of the Great Hungarian Plain annually. Due to the lower number of tillage operations, there is a 30-50% decrease in fuel consumption and an environmental load of greenhouse gases can be expected. *Economic consciousness:* Shifting to reduced tillage from conventional probably needs the purchase of new machinery. *Relevant TALA question in the questionnaire:* Do you consider changing the management system of your cropland from conventional to reduced tillage in the near future? If yes, why? If not, why not?

Application of soil reclamation and/or soil conditioning

Environmental consciousness: According to the research achievements of RIK, 6 years of soil conditioning (use of Neosol once a year at a rate of 150 kg/ha) the soil depth with favourable physical, chemical and biological status increased by 10 cm in a meadow chernozem soil. *Economic consciousness:* Without yield depression, about one third of the autumn basic fertilizer can be saved. The cost of soil conditioning per hectare is about 25-30 thousand HUF per year. *Relevant TALA question in the questionnaire:* Do you plan to use a soil conditioner in your area in the near future? If yes, why? If not, why not?

Application of manure and/or compost

Environmental consciousness: According to the research achievements of RIK, the basic autumn fertilizers can be replaced with compost without yield depression. In addition, the organic matter and lime content of compost significantly improves soil cultivability, reduces soil acidity, and provides nutrients for the crops for several years. *Economic consciousness:* The cost of using compost per hectare is about 50,000 HUF per year, or 100,000 HUF every three years. *Relevant TALA question in the questionnaire:* Do you plan to use manure/compost in your area in the near future? If yes, why? If not, why not?

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Pilot study with the Advisory Board members

A pilot study was conducted on 5 farmers of the Advisory Board of RIK, Hungarian University of Agriculture and Life Sciences. In 2014, the director of RIK formed an advisory board (AB) with the goal to make a formal and informal platform to link agricultural research and practice. The AB members, who cultivate more than 10,000 ha of land. These representatives (executive managers) of farms typical in the Great Hungarian Plain were the best people to link us with the local agricultural practice and provide answers to different soil related environmental challenges experienced by them and how they tackle these issues. They were interviewed about three issues relevant to soil related environmental topics being important for the farmers of the Great Hungarian Plain and are in harmony with the first 3 topics of the TALA questionnaire:

1. adaptation to extreme agroecological conditions by conversion from conventional to a water preserving soil cultivation system or by irrigation,
2. protection against soil degradation by soil reclamation and/or soil conditioning,
3. enhancement of soil fertility by the application of manure or compost.

The data collected was to critically analyse the soil related environmental consciousness of farmers and gave information how to encourage appropriate agrotechnology selection when conducting farming activities. Through the answers to the questions involved in the questionnaire, we get to know more what influences farmers in the selection of agrotechnological elements, whether they have sufficient environmental and professional considerations.

We conducted a combined assessment of the answers gained from the questionnaires and the opinions of the AB members. The form of data obtained during the investigation was qualitative and was subjected to simple processing in Microsoft Excel to calculate percentages. A chi-squared test was used to determine if there is a relationship between the interest or difference among the groups of farmers responding yes and no to the specific questions involved in the TALA questionnaire. A significance level of 0.05 was selected, which indicates a 5% risk of concluding that an association between the variables when there is no actual association. To simplify the study the questionnaire was made to respond yes and no, yes indicates the consciousness of each farmer in each question while, the answer no, means that exists an opportunity to share information to create consciousness. The null hypothesis was that there is no difference between the groups of farmers responding yes and no, hence there are farmers with and without the willingness to introduce or apply the specific investigated agrotechnical element equally. Each surveyed topic was tested statistically to clarify the level of consciousness. The number of possible outcomes in the given chi-square is 2, the degree of freedom is 1 ($2 - 1 = 1$). The critical value (3.8) was used to tell the boundary of extreme that we need to reject the hypothesis.

Results

Application of water preserving soil cultivation systems

One of the AB members thinks that the most important possibility to accommodate the extreme agroecological conditions is the application of water preserving soil cultivation. The principle is the reduction of the number of tillage operations to avoid drying out of the soil. They introduced the application of water preserving soil cultivation in 2017. The main limiting factor of the high price (30-35million HUF) of the specific machinery needed. The other main possibility of accommodation is irrigation. Recently they irrigate about 100 ha, but they want to enlarge the irrigated area. The main limiting factor of the development of irrigation is bureaucracy. There are several proposals announced for the development of irrigation, but it is almost impossible to fulfil all the requirements in due time.

"Irrigation, irrigation, irrigation" – was the opinion of another manager of the AB. He thinks that irrigation should be used in larger areas. He mentioned another possibility of accommodation, namely the mitigation of the heat stress of the crops ensured by early sowing. They also use foliar fertilization to make the crops stronger so less sensitive to stresses. They are continuously investing in the machinery of conservation tillage, especially they believe in deep loosening.

There are several farms where irrigation has been applied for decades. Beyond irrigation, they also consider conservation tillage to be the most important accommodation possibility under extreme agro-ecological conditions. Nevertheless, converting from conventional to conservation tillage is just under process which needs to purchase new machinery.

On some farms, to mitigate the unfavourable relief of the irrigated plots, they applied a grader (creating a flat soil surface) and created surface drains. This operation ensured a much favourable water regime of the soil, no excess water has occurred since it was done. It has significance when a high amount of rainfall takes place in the vegetation period. According to their experiences, 20% of loss could be expected if the soil relief was not even.

The AB member involved in organic farming told that irrigation was not allowed to be applied for them except for vegetables. They do not plan the introduction of irrigation in the farm, they rather apply moisture-saving soil cultivation methods. The tillage they apply is based on deep loosening. In the old days, it was taught that deep loosening must be carried out every 4 years, but recently 2-year frequency is more rational. The manager thinks that the purchase of energy and water-saving machinery should be subsidized by the state. Irrigation in itself is not suitable to mitigate the harmful effect of climate change. Recently there are several forums about the development of irrigation but most of the people talking about irrigation are not experts. Beyond irrigation, the proper selection of crop varieties and hybrids is also of great importance, especially in terms of their stress tolerance. They think that the production of region-specific varieties is a key factor in the accommodation of extreme ecological conditions.

In topic 1, the responses to the question in the questionnaire if the farmers would consider changing the management system of their cropland from conventional to water preserving tillage are shown in Figure 1.

The descriptive analysis revealed that among the interviewed farmers 36% would consider changing the management system of their crops from conventional to reduced tillage while 64% would not. The study shows out of the 36% that would consider change, 68% was due to the positive experiences they have had when applying, 18% of the respondent would consider changing due to the belief that it has a positive environmental impact, 11% of the respondents said they may consider under subsidy and 3% stated their belief on positive economic impact as being the reason for wanting to change to reduced tillage. Out of the 64% that would not consider changing their management practices, 74% said no due to the requirement of changing the machinery and insufficient land, 15% due to high soil compaction, 10% due to their age and lack of interest as being the reason for not considering change, and 1% would not consider due to plant protection problems.

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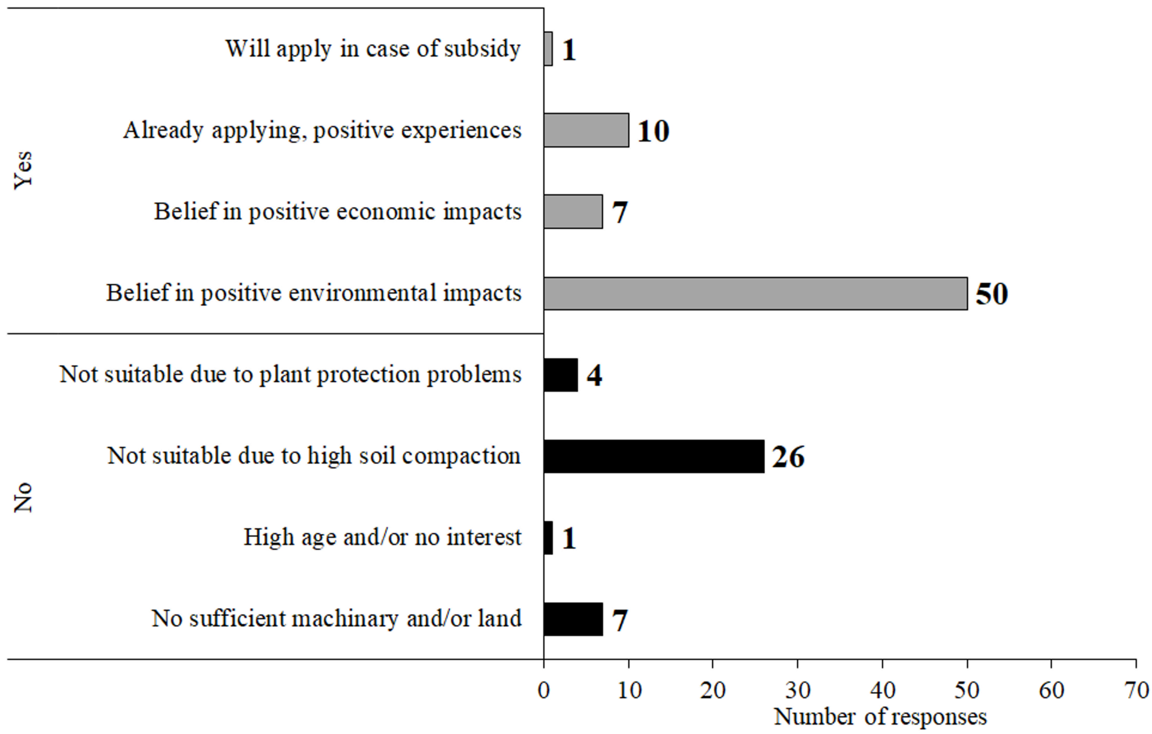

Figure 1: Opinions of 106 farmers about the conversion from conventional to a water preserving soil cultivation system

Application of soil reclamation and/or soil conditioning

Recently, there are no direct subsidies especially dedicated to soil reclamation, when there was, it was very useful, according to the opinion of the interviewed farmers. They do some soil reclamation, approximately 1/3 of their lands is reclaimed where cereals, alfalfa are produced and also the pastures. In the Great Hungarian Plain, there are extended areas with salt-affected soils, even there are salty spots in the plots with better soils too. Recently, farmers generally do not reclaim the chemically degraded areas but often keep them as a fallow, which meets the requirements of fallow regulations by the European Union (EU). They think that greening is a potential kind of payment support given to farmers for them to adopt or maintain farming practices that help meet the environmental and climate aims. Through greening, farmers are receiving rewards from the EU for conserving the natural resources and maintaining public goods, which are beneficial to the public and are not reflected in market prices.

They also use the salt-affected areas to meet the requirements of fallowing. Some areas with salt-affected soils (SAS) are not under irrigation and reclaimed by liming (low dose of 300 kg/ha), but that is not really typical. SAS are utilized by growing relatively salt-tolerant crops (mixture of clover and grass), but most of the farmers have been struggling with this problem for decades. Some other farmers working on the worst SAS created fishponds, which is an intensive use of areas with unfavourable soil properties, especially on heavy textured clay soils with low water permeability. On the areas where only spots of salinization appear, farmers prefer growing alfalfa for seed production, and they do not plough. According to their observation, the fructification (formation of seeds) of al-

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falfa is more successful on sodic soils. All the interviewed farmers highlighted the importance of liming, they suggested that liming should be subsidized.

Regarding soil conditioning, they also have the opinion that the selection that of the proper product is very problematic, therefore they need support in this respect. Without researched based establishment, most of them consider some soil conditioners as effective as 'blessed' water. Plenty of farmers have already tried soil conditioning in production of different crops, but so far, they could not figure out the positive effect of the soil conditioner they applied. Nevertheless, they did not say it was not efficient at all. The selection of soil conditioner that is effective for their conditions is very difficult because there are too many offers but no background of the scientific establishment. One of the managers had negative opinion about soil conditioning as there are too many companies and dealers praising their products, but he could not be persuaded by any of them showing evidence about significant differences due to the application. For justification, the help of agricultural research institutes like RIK would be very helpful, as they said.

In topic 2, the responses to the question in the questionnaire if the farmers would consider applying soil reclamation and/or conditioning are shown in Figure 2.

The result of the analysis of the questionnaires indicated that 52% of respondent farmers would consider applying soil reclamation on their farm in the future, while 48% would not. Out of the 52% who would consider applying the soil conditioner, 55% were already applying and they have a positive experience, 22% would consider but on small scale, 16% believe in its positive environmental impact, 5% would consider applying because it increases yield and its cost-efficient and 2% gave no explanation why they would consider applying conditioners. Out of the 48% of the respondents who would not consider applying the soil conditioner, 37% had no interest, 29% considered soil conditioner to be too expensive, 18% preferred applying the manure instead, 14% had no information regarding soil conditioner and 2% did not explain.

Application of manure and/or compost

Farmers in the Great Hungarian Plain used to have a sufficient amount of manure before the close of most of the dairy cattle farms. In general, the applied manure only on the irrigated areas every 3–4 years, always under ploughed. The distribution was a time and labour-consuming activity, needing four workers for more than a month. They think that the high yields that could be achieved on the irrigated areas were also due to the more favourable soil structure generated by the application of manure.

The general problem was that where there is no animal husbandry in or near the farm, they do not use manure. The application of mineral fertilizers is mostly based on analytical surveys but also influenced by the actual financial possibility. Sometimes they applied chemical amendments to reclaim the soil but these can be considered only trials.

Only two of the interviewed farmers use manure on 15% of the area (they have a pig farm and some beef cattle). Where they deal with animal husbandry, they prefer the utilization of manure generated by the animals. When they apply manure, they always mix it into the topsoil by ploughing (it means they do not use it on SAS). On the better farms, plant nutrition is strictly based on the result of laboratory analysis of the soil including organic fertilization plans.

Another importance of manure application was highlighted by farmers doing organic farming. They think that one of the fundamental bases of organic farming is the application of manure. The distribution is very expensive but there are no other options. Or-

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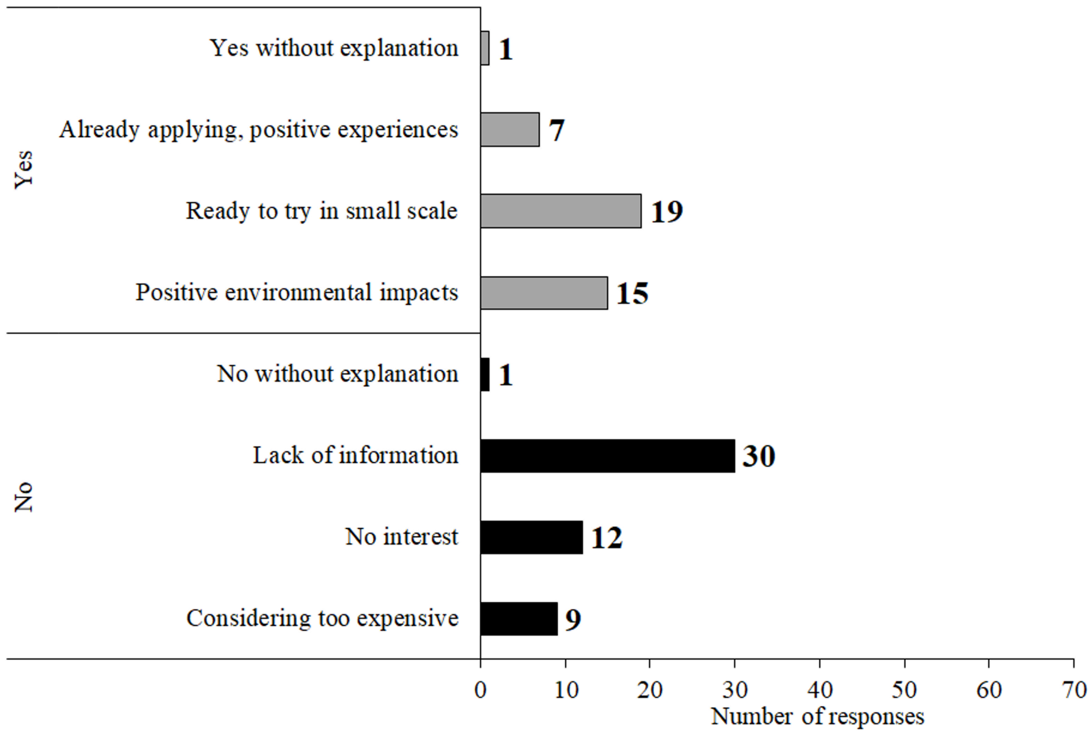

Figure 2: Opinions of 106 farmers about the application of soil reclamation and/or conditioning

ganic farmers apply manure every four years as the worst case, but they try to do it more frequently. The manure is processed, they make compost of it by adding some herbs to it. They also use dolomite and alginate to reclaim their soils.

In topic 3, the responses to the question in the questionnaire if the farmers want to apply manure are shown in Figure 3.

The result of the analysis showed that 88% of the farmers would consider the application of manure and/or compost instead of mineral fertilizers, while 12% of the respondent would not. Out of the 88% that would consider, 63% would consider due to the positive environmental impact, 27% due to believing in its positive economic impact, 7% were already considering, while 3% would consider but did not give any explanation. Out of the 12% of the respondents that would not consider manure application, 33% of the respondents would not because they harvest the straw for litter only (livestock keepers) and do not utilize further. 33% had negative experiences, 25% had no interest, while 8% did not give any explanation.

Discussion

The results of the chi-squared test used for analysing the willingness of the farmers to introduce or apply the investigated agrotechnical elements are shown Table 1.

In the topic of soil cultivation, since the p value $\leq \alpha$, we rejected the null hypothesis. This means that statistically, the investigated farmers differ in this respect. We consider a low level of willingness of them to change their soil cultivation methods from conventional to reduced/water preserving tillage as the rate of yeses was statistically low. In the topic of soil reclamation/conditioning, since the p value $> \alpha$, we did not reject the null

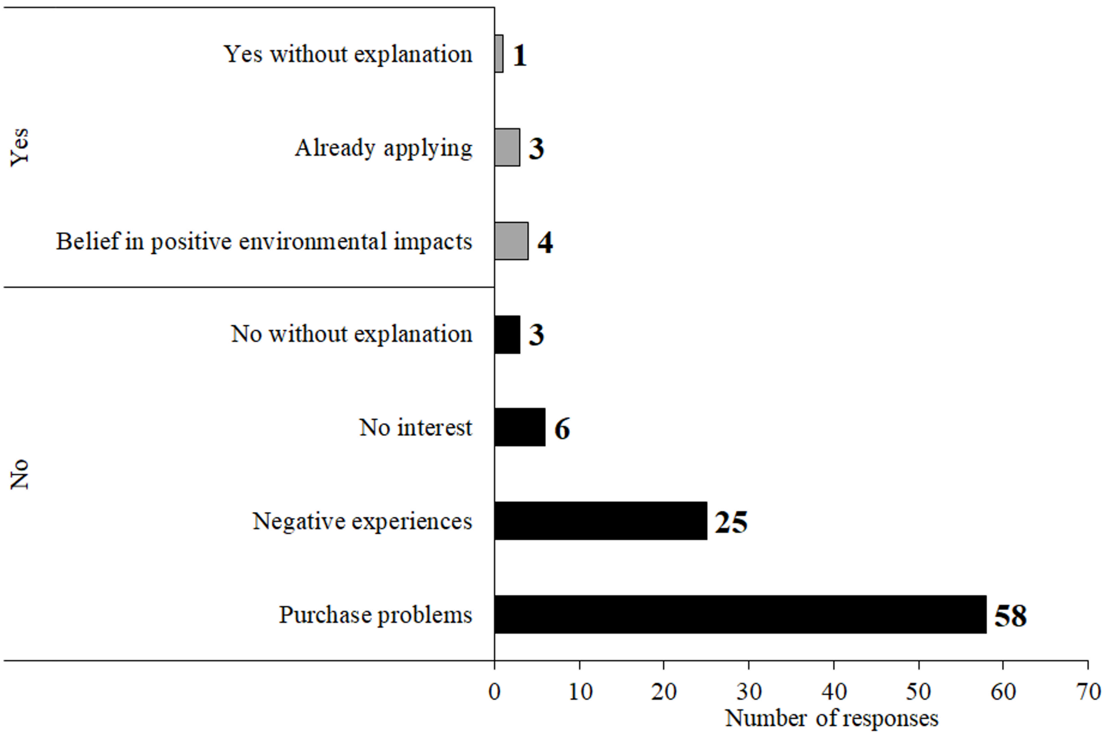

Figure 3: Opinions of 104 farmers about manure/compost application

Table 1: Result of the chi-squared test regarding the investigated topics

Topic	Yes	No	χ^2	*P* value	Level of willingness
Soil cultivation	37	69	9.66	0.00	Low
Soil reclamation/conditioning	54	52	0.03	0.85	Moderate
Manure/compost application					
92	12	61.53	0.00	High	

hypothesis. This means that statistically the investigated farmers do not differ in this respect. We consider a moderate level of willingness of them to apply soil amendments/-conditioners as the number of yeses and nos was almost equal. In the topic of manure/-compost application, since the p value $> \alpha$, we did not reject the null hypothesis. This means that there is only 43% probability the two groups of farmers differ from each other. We consider a moderate level of willingness of them to apply compost on their lands as the number of yeses and nos was close to each other.

Conclusions

Soil degradation is a problem that the farmers have been facing for many years and its continuing to spread across the farmer over the years. Recently, they cannot reclaim all their land, one farm manager mentioned that he can only be able to reclaim 1/3 of his total farmland due to lack of subsidies, on affected lands they produce cereals, alfalfa, and keep them as fallow. They also produce salt-tolerant crops (mixture of clover and grass) and create fishponds which are more successful grown on sodic soils.

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The managers of the interviewed farms experience secondary salinization as they irrigate their farmlands. They face problems in water management especially in the irrigated plots due to high unexpected rainfall after they have irrigated their plots. Another farm manager could not irrigate his farm as he has an outdated irrigation system and the other was due to the issue with water quality as it has high salt concentration and other pollutants.
The supply of plant nutrition and soil conditioning by the farmers for organic fertilizer was based on financial possibility and raring of the animal in the farm to supply the farm with the manures. For those who do not keep or have stopped raring animals, they do not supply organic fertilizers to their farms. The farm managers have no confidence in soil conditioning as they say there are many companies and dealers but they are not so reliable as they lack scientific proof.

Based on the result of the analyses, we found that the greater number of the farmers are both economic and environmental conscious, as the result of the study showed that the majority are aware of the environmental impacts of the investigated agrotechnological elements. The availability of cheaper alternatives, costs, profits, and lack of interest as being factors that influence farmers' decisions in the selection of agrotechnological elements. Even those who consider changing to environment-friendly technologies would only do it under subsidies due to the high cost involved and they would only try the technologies under small-scale production. We do believe that the collected information can be used to encourage environmental awareness among farmers, the results contribute to an increase in quality of crop production, reduce costs and protect the environment for the future generation.

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