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National Agricultural Research Center

Technical Report

Farmers' Attitudes Towards Treated Sludge (Biosolids) use in Agriculture: Evidence from Jordanian Badia

Photo credit: Dr. Hamzeh Rawashdeh (NARC-Jordan, 2020)

Tracing soil amendment impacts of processed wastewater sludge on the rehabilitation of Jordan's agro-pastoral areas (TRACE- Rehab)

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LIST OF ACRONYMS

DOS	Department of Statistics
Du	Dunum (1 du=0.10 ha)
Ha	Hectare
ICARDA	International Center for Agricultural Research in Dry Areas
JD	Jordanian Dinar (1 JD= 1.41 US$)
Kg	Kilogram
MoA	Ministry of Agriculture
NARC	National Agricultural Research Center

KEY MESSAGES

Summary

The application of treated sludge (biosolids) on agricultural land has been widely acknowledged, given the cost-effectiveness of this method and its easy use. When appropriately applied to agricultural land, sludge can replenish organic matter and nutrients in the soil. Although treated biosolid has been used in agriculture in many parts of the world, its acceptability varies with farmers' different cultures and beliefs. Literature review reveals that farmers' concerns on sludge use are primarily due to its anthropogenic origin, pollutants that it carries, and a general perception of treated biosolid being unsafe and risky.

This research investigates farmers' perceptions of land application of treated sludge (biosolid) on their farm. This study targeted *Al Majeddyeh* farming community located in Jordanian *Badia.* Surveys were conducted with randomly selected 20 farmers in this village. Overall, farmers' perception of land application of treated biosolids is negative, and the majority of the farmers don't want to use treated biosolids for several reasons such as their trust in the suitability of the treated biosolid; concerns on the consumed product (transfer of disease); lack of knowledge on the biosolid properties and advantages and disadvantages of sludge use in agriculture. In terms of the most critical factors influencing farmers' fertilizer purchasing decision were: the safety of fertilizer, nutrient content, organic matter, water holding capacity, recommended by a trusted source, suggested volumes apply, price of the fertilizer, fertilizer application, and know of someone who used it. The survey also revealed that all respondents didn't use treated biosolids before. In terms of accepting manure mixed with biosolids, most of the respondents refused manure mixed with biosolids, and only 20% accepted this mixture.

This study's findings are valuable for Jordanian decision-makers in their roles to promote the use of treated bio-solid sludge as fertilizers and soil conditioners. The Agriculture and Extension Services in the Agriculture Ministry should encourage farmers to use treated sludge (biosolid) in their community. Results suggest that land application of biosolid sludge can be accepted by more farmers if farmers are well trained for the safe and effective use of treated biosolid. Launching awareness programs about the benefits of treated biosolids and improving farmers' perceptions on its land application; raising public awareness by holding training workshops and conducting surveys about the efficient application of treated sludge (biosolid).

Keywords

Land application; Agriculture; Treated biosolid; Agropastoral system; Farmers' perception; Fertilizer; Jordan *Badia*.

Highlights

- Farmers' perception of land application of treated biosolids is negative in *Al Majeddyeh* region.
- The primary reasons for no using treated biosolids are technical factors:
    - Do not trust that biosolids are suitable.
    - Concerns on the use of these materials in the production of crops for human consumption.
    - Special needs are associated with biosolids used.
    - It is Harmful to animals and then to humans (transfer disease).
    - Sheep don't graze on barley inland treated with biosolids.
- The most critical factors influencing farmers' fertilizer purchasing decision are:
    - The safety of fertilizer, nutrient content, and organic matter;
    - Water holding capacity;
    - Recommendation by a trusted source and knowledge someone who used it;
    - Volumes to apply, price of the fertilizer, and fertilizer application.
- There is a refusal to accept manure mixed with biosolids.
- There is a need to increase farmers' awareness and perception of biosolids' benefits and impacts on land application.

I. INTRODUCTION

Jordan has a land area of about 90,000 km2 and is classified into three main topographic zones: the Jordan Valley, Highlands, and rangeland (Ababsa, 2013). Jordan's 2015 Agriculture Law No. 13 defines rangelands in Article 35 as "all lands registered as such and any other state-owned lands where annual rainfall is below 200 mm and does not have sustainable irrigation, or the lands confined for public use". The updated Rangeland Strategy for Jordan states that: rangelands are "the wide-open, non-fenced lands where fodder grow naturally, that is not suitable for traditional farming due to lack of rain, low fertility, rough terrain, and high rockiness or because of a combination of these factors which makes the lands optimum use restricted to the production of fodder for animals" (Updated Rangeland Strategy for Jordan, 2013/2014). Despite the low rainfall received, occasional storms cause surface runoff, wadi (or gully) flow, and even flash floods. There is diurnal and seasonal variation in temperatures, radiation, and winds (Al Ayyash et al. 2008). According to the definition of rangeland and the isohyet map of Jordan, rangeland covers around 90% of the country. Jordan's rangeland is widely used by pastoral communities for sheep, goats, and some camels grazing. Pastoral communities are known as *Bedu* in Jordan and across the Middle East; therefore, the area where *Bedu* is known as *Badia*. The Jordanian *Badia* stretches from Jordan's highlands to Syria, Iraq, and Saudi Arabia; and beyond Jordan's borders and covers 90 % of Saudi Arabia, 75 % of Iraq, and 55 % of Syria (Al-Tabini et al. 2012).

Before 1990, the annual land production of dry matter was estimated at 80 kg/ha; later, it decreased by 50%, increasing pastoral systems' vulnerability (Al-Tabini et al., 2012). Natural and anthropogenic factors have led to Jordan's dry rangelands becoming increasingly prone to degradation. Land degradation is primarily driven by wind and water erosion, causing a decline in soil fertility and habitat degradation; it occurs due to overgrazing, unsustainable land management practices, rapid population growth, and socio-economic changes, including refugee fluxes, urbanization, and poverty. These factors forced dryland farmers and herders to adopt unsustainable practices to produce fodder to meet their needs, such as barley cultivation. Jordan's land degradation not only affected the rangeland ecosystem and its functionality but even hurt the entire country (Karadsheh et al., 2012). Because of the droughts and overgrazing, vegetation and soil degradation have led to surface crusting, negatively affecting rainwater retention and infiltration and speeding up both surface runoff and soil erosion (Strohmeier et al., 2021).

The biosolids, originating from the treated sewage sludge, is the organic product of the sewage treatment system, rich in organic matter and nutrients, especially nitrogen and phosphorus, with agricultural potential for isolated use or in combination with mineral compost (Lemainski and Silva, 2006a; 2006b). Thus, the agricultural recycling of biosolids is a viable alternative for the final destination, since, besides the acknowledged presence of several nutrients in its composition, there is an equivalence of performance when substituting the chemical fertilizers (Hall, 1995; Backes et al. 2009; Adair et al. 2014). On an international level, land application of biosolids is still the most widely used management approach. For instance, in the USA, over 50% of the produced biosolids are land applied (Breulmann et al. 2015). Land application is not only relevant for agricultural production but also for land restoration (Breulmann et al. 2020).

In Jordan, several standards are concerned with further assessing the quality, use, transport, and disposal of the biosolids. Standards of the Ministry of Agriculture (MoA) don't allow biosolids to be used in agriculture yet; therefore, there is no reuse of biosolids in the agricultural sector. Ministry of Agriculture is taking care of the agriculture reputation and export quality and standards related to agriculture inputs. Furthermore, biosolids are not directly reused for any other purpose in Jordan. The only exception is the biosolid of the Al Samra wastewater treatment plant (WWTP), where the biosolids are being used for biogas production through anaerobic digestion to produce

electricity for running the facility. The Ministry of Environment (MoEnv) sets specific standards on the types, transportation, and places to use it. The MoEnv law of: 'Instructions of Organizing the Storage, Transport, and Treatment of Organic fertilizers and their Trading for 2009' and MoA: 'Instructions for the Requirements of Licensing, Preparation, Storage, Handling and Trading of Fertilizers and Plant Growth Regulator for 2011' prohibit the production of organic fertilizers from biosolids, and refer to JS 962 (2011). The Ministry of Water and Irrigation (MoWI) has set several monitoring programs for biosolid monitoring, treatment, and use, which are well bounded by national and international standards and protocols. In Jordan, the standard JS 1145 (2016) regulates the production, transportation, and reuse of biosolids. JS 1145 (2016) classifies biosolids into three classes and restrict the final fates of each class. Type I and Type II sludge can be used as a soil amendment in rangelands, and Type III sludge can only be transported to sanitary landfills. The standard makes no clear distinction between Type I and Type II sludge in terms of selected crops, rates of applications, and conditions of application. The maximum rate of application for both Type I and Type II sludge is 6 tons/ha per year, and soil amendment with biosolids can only be performed in areas with less than 200 mm of average annual rainfall. Suleiman et al. (2010) indicated that the biosolids of Jordan are with higher quality concerning heavy metals content and are far below the limits indicated in the JS 1145 (2016) and besides that, the high nitrogen content is high, which found to be around 4% for biosolids from the Wadi Mousa and Wadi Hassan WWTPs.

Independent of the crop that will be planted, the attractiveness of the rural farmers opting for organic fertilization increases when the cost-effect relationship is considered favorable. Thus, organic fertilization is one of the most important ways to improve soil quality and prevent it from drifting. We return the organic matter through fertilization, which is consumed by the plants, to the soil –and this improves soil structure. Organic matter binds soil granules to each other and prevents them from drifting. If we add organic fertilizer to the sandy soil, it will store more water and become rich in nutrients. Indeed, the farmyard manure can be obtained from the fermentation of plant residues such as hay, wood, larch, market, leaves, etc., with significant influence of microbes spread everywhere and suitable for particular conditions. The use of compost (composted plant and animal materials) to maintain or improve soil organic matter is supported by many research and development organizations given its multiple benefits as a soil amendment and a source of organic matter by improving soil biological, chemical, and physical characteristics.

II. STUDY OBJECTIVE

In Jordan, a few studies have targeted farmers' perception and attitude on land application of biosolids in agriculture. It is within the activities of "Tracing soil amendment impacts of the biosolids on the rehabilitation of Jordan's agro-pastoral areas (TRACE Rehab)" project, the socio-economic research directorate at the National Agricultural Research Center (NARC) in collaboration with the International Center for Agricultural Research in the Dry Areas (ICARDA) undertaken a study to investigate farmers' perceptions assessment of their acceptability, and views on land application of biosolids and compost on their farms/agro-pastoral communities with a particular focus on their attitudes towards the use of biosolids and compost and potential factors influencing farmers decision to use biosolids.

Within this context, the purpose of this study is to investigate farmers' perceptions of land application of treated biosolid on their farms/agro-pastoral communities in Jordan. Thus, understanding farmers' perceptions and opinions about the use of biosolid based compost (biosolids) will ensure the capitalization of the existing opportunities to address the dual challenge of waste management and soil nutrient depletion in Jordan via the safe recovery of nutrients from both solid and liquid waste streams for reuse in agriculture.

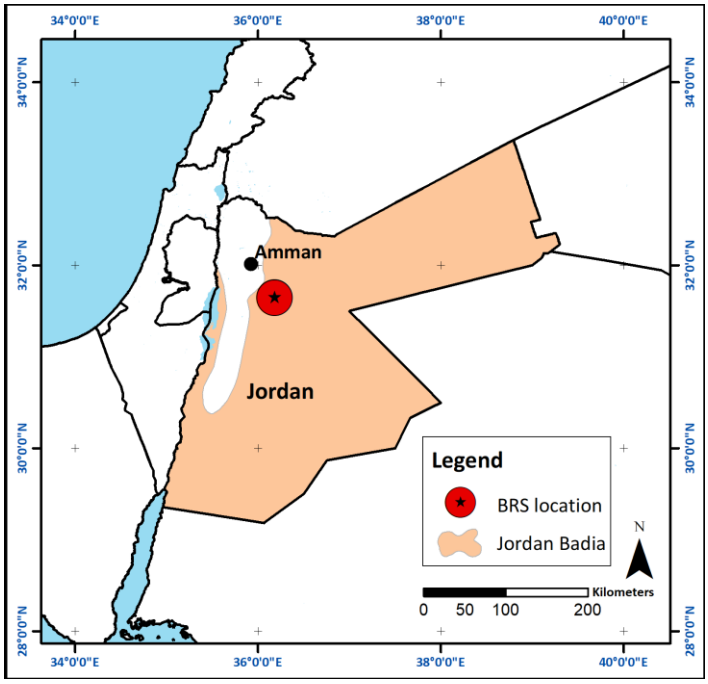
- To have an idea about the types of fertilizers used in rainfed agriculture at *Al Majeddyeh*.
- To know the drivers for adoption or rejection of using organic fertilizers in agriculture.
- To have an idea about local production and marketing of organic fertilizers.

III. METHODOLOGICAL FRAMEWORK

III.1. Study area

This study focuses on the rural communities of *Al Majeddyeh* village at *Al Muwaqer* district, which is located in the southern part of Amman, with a population of (441 inhabitants and the number of households is (40) families, the family number range is about (5) members according to the Jordanian Department of Statistics (DOS, 2020). *Al Majeddyeh* centered at the latitude 31.742452; the longitude is 36.116534 with an average elevation of 831 m above sea level. The average rainfall is around 130 mm, and the estimated area is (600) dunums, and the farmers' land holdings vary from (0.5 to 60) dunums (Figure 1). The old name of the former area, "*Al-Matabba,*" has been changed to *Al Majeddyeh*. The residents of *Al Majeddyeh* are from the same family, which is the *Bani Sakhr* tribe. The houses in the area are characterized by concrete buildings, some of them are built from stone, and everyone lives in his own home.

Figure (1): Location of Al Majeddyeh in The Hashemite Kingdom of Jordan



Source: Strohmeier et al., 2021.

III.2. Data collection and methodological procedure

In this study, a socio-economic survey was conducted in the form of interviews, and 20 farmers from *Al Majeddyeh* were randomly selected. The questionnaire consisted of a mix of structured and open-ended questions and supplemental questions. Questions include farmers' age, residence location, educational level, size of the cultivated area for different crops, and a quantity and type of fertilizer used. The data collected will help assess farmers' perceptions and attitudes of biosolid-based compost and define potential factors influencing their willingness to use /or not this type of fertilizer (i.e., biosolid-based compost). Besides the interviews, the socio-

economic team facilitated a focus group meeting to collect qualitative data using pre-selected questions and phrased them to promote open dialogue between the facilitator and farmers.

The collected data were analysed using descriptive statistics such as mean and percentage. The Likert scale (5-Points response scale) used in which responders specify their level of agreement to a statement by indicating one of the following: (1) not at all influential, (2) slightly influential, (3) somewhat influential, (4) very influential, and (5) extremely influential. The Statistical Package for the Social Sciences (SPSS) version 18 was used to analyse the collected data.

IV. EMPIRICAL RESULTS AND DISCUSSION

IV.1. Socio-demographic characteristics of the households

The demographic characteristics of the respondents for various–variables are presented in Table 1. The results revealed that the sex of respondents is 100% male. Also, the head of the household in the survey is 100% male. The age of respondents ranged from 20 to 70 years old, with a mean of 41 years. Around three-fourth of the respondents' age (75%) fell between 20 and 52 years, implying that they are active and productive. Their marital status included 16 married (80%) and 4 single people (20%).

Regarding educational level, about 65% of farmers were high school graduate, and about 5% of the respondents were able to read and write, and 5% was Illiterate, although there were 15% bachelor's degree and Above. About 45% of the household heads are farmers, while about 30% retired, 10% are governmental employees, 10% have private businesses, and 5% are real-estate dealers. According to the survey, the average family size is 7 members, where the minimum family size of the interviewed is 3 members, and the maximum is 14 members.

Table 1: Socio-demographic characteristics of the households

Demographic characteristics		Count	Percentage %
Sex	Male	20	100%
	Female	0	0%
Female-headed household	Yes	0	0%
	No	20	100%
Age	Min: 20	Max: 70	Mean: 41
Marital status	Married	16	80%
	Single	4	20%
Educational level	Illiterate	1	5%
	Read and Write	1	5%
	Elementary	2	10%
	High School Graduate	13	65%
	B.S and Above	3	15%
Occupation	Farmer	9	45%
	Governmental Employee	2	10%
	Private Business	2	10%
	Dealer	1	5%
	Retired	6	30%
Family size	Min: 3	Max: 14	Mean: 7

Source: Own elaboration from field survey (2020).

The survey results showed that 90% of the households own their land, while 10 % don't own land. The Median land area is 24 du, where the minimum area size was 1 du, and the maximum was 506 du. Experience in agriculture of the sampled households was from 4 to 44 years, with

18 years. As for the average living years in the community, it was 19, about 35% of them living 20 years where the minimum years of living were 1 and the maximum years of living were 54 years. About 70% of respondent are a member of *Al Majeddyeh* association while the average years of membership are 7 years, where the minimum years of membership are 2 years and the maximum years of membership are 14 years (Table 2).

Table 2: Socio-demographic characteristics of the households

Survey Question	Answer	Count	Percentage %
Status of landownership	Do not own land	2	10%
	Own land	18	90%
Area Size	Min: 1	Max: 506	Median: 24 Mean: 96
Experience in Agriculture	Min: 4	Max: 44	Mean: 18
How long have you lived in this community?	Min: 1	Max: 54	Mean: 19
Are you a member of any farmer's association (cooperative, CBO, etc.)?	Yes	14	70%
	No	6	30%
How long have you enrolled by the association?	Min: 2	Max: 14	Mean: 7

Source: Own elaboration from field survey (2020).

IV.2. Agriculture farming systems analysis

The results displayed in table 3 revealed that about 70% of the total respondents have other sources of income other than agriculture, where 50% of them are retired, and the rest are employed in different jobs (i.e., 14% governmental employee, 14% private company 7% delivery and transport, 7% real estate's dealer, and 7% other).

The average income ranged from 20% to 100%, while the percentage of the income source of real estate's dealer is 100%, 83% private company, 85% government employee,67% retirement, and 50% delivery and transport. Regarding the main source of income, the results indicated that most respondents depend on crops planting 30% and livestock 30% while other respondents depend on retirement salary 20%, employment (labor) 6.7%, and private business 14%. However, the net household income of all respondents is less than 1410 $. The results indicated that respondents' employment status is 52% farm work, 21% retired, 14% full- time employment, 10% part-time employment, and 3% unemployment.

Table 3: Agriculture farming system - Sources of income

Survey Question	Answer	Count	Percentage
Do you have income other than agriculture?	No	6	30%
	Yes	14	70%
Sources of income other than agriculture	Governmental employee	2	14.3%
	Real estate's Dealer	1	7.1%
	Retirement	7	50%
	Private company	2	14.3%
	Other	1	7.1%
	Delivery and transport	1	7.1%
Income percentage %	Min: 20	Max: 100	Mean: 70
Percentage **of income** sources	Governmental employee		85%
	Real estate's dealer		100%
	Retirement		Average: 67%
	Private company		Average: 83%
	Other		30%
	Delivery and transport		50%
The main source of income	Livestock	9	30%, P. of cases: 45%

	Crop's planting	9	30%, P. of cases: 45%
	Private business	4	13%, P. of cases: 20%
	Employment (labour)	2	6.7%, P. of cases: 10%
	Retirement	6	20%, P. of cases: 30%
Net Household income (US$/month)	Less than 1410 $	20	100%
Employment Status	Full- time Employment	4	13.8%, P. of cases: 20%
	Part - time Employment	3	10.3%, P. of cases: 15%
	Unemployment	1	3.4%, P. of cases: 5%
	Retired	6	20.7%, P. of cases: 30%
	Farm work	15	51.7%, P. of cases: 75%

Source: Own elaboration from field survey (2020).

The analysis results indicated that 90% of respondents own farmland, and 94% of these respondents' own farmland inside *Al Majeddyeh*. According to the renting land, 50% of respondents rent farmland inside *Al Majeddyeh*. The analysis also indicated that the leased land's average size is 158 du; the median size is 130 du, while the minimum size of rented land is 30 du, and the maximum is 500 du. The average area of cultivated land is 165 du, the median size 111 du while the minimum size of cultivated land is 1 du, and the maximum is 1006 du (Table 4).

Table 4: Agriculture Farming System - Farm land ownership

Survey Question	Answer	Count	Percentage %
Do you own any farmland?	No	2	10%
	Yes	18	90%
Where?	Inside *Al Majeddyeh*	17	94%
	Outside *Al Majeddyeh*	1	6%
Do you rent any farmland?	No	10	50%
	Yes	10	50%
Where?	*Al Majeddyeh*	10	100%
What is the size of your rented land?	Min: 30	Max: 500	Mean: 158 Median: 130
What is the size of your cultivated land? (du)	Min: 1	Max: 1006	Mean: 165 Median: 111

Source: Own elaboration from field survey (2020).

The respondent (11 farmers) to the survey cultivated olive whereas the average olive size land is 4 du where the minimum size of olive land size is 1 du, and the maximum is 10 du. The 11 farmers of respondents didn't use organic fertilizer, Although the 11 farmers of respondents used manure as fertilizer, whereas the mean of several times of using fertilizer is 1.7. In contrast, the minimum number of times of using fertilizer is 1 time, and the maximum number of times of using fertilizer is 2 time. One respondent who cultivated olive mentioned that the quantity is 30 kg olive/du, other respondents who grow olive said that the production is 8 kg olive oil/du (Table 5).

According to the respondent to the survey cultivated barley, the average size of barley is 181 du, where the minimum size of barley is 2 du, and the maximum is 1000 du. However, the study area's principal crops are barley, olive, and one respondent cultivated vegetable in 2 du in

Marab[1]. About 70% of respondents grew barley for grazing, 22 % for harvesting, and 9 % for sale before harvest (crop lease).

Table 5: Agriculture Farming System - Olive cultivation

Survey Question	Answer	Count		Percentage %
Size of olive land (du)	11 farmers	Min: 1	Max: 10	Mean: 4
Do you use organic fertilizer?	No	11		100%
	Yes	0		0%
No. of Times of using fertilizers/ year	11 farmers	Min: 1	Max: 2	Mean: 1.7
Specify fertilizer type	Manure	11 farmers		100%

Source: Own elaboration from field survey (2020).

Sheep, which graze on barley after harvesting or before, ranges from 4 heads to 800 heads with an average of 130 heads. Also, grazing duration ranged from 1 month to 3 months, with an average of 2.6 months. This is mainly because of feeding livestock of barley when there is no barley sepal, and when there is the production of barley, the livestock herds graze in the leftovers of the harvest (Table 6). It also appears from the table below that 7% of respondents who cultivated barley used manure fertilizer for barley cultivation, whereas 83% didn't use any fertilizer. Whereas the mean number of times of using fertilizer is one farmer.

Table 6: Agriculture Farming System - Barley cultivation

Survey Question	Answer	Count		Percentage %
Size of Barley (du)	18 farmers	Min:2	Max:1000	Mean: 181 Median: 136
Uses of Barley	Grazing	16	69.6%	P. of cases: 88.9%
	Harvesting	5	21.7%	P. of cases: 27.8%
	Selling before harvesting (crop lease)	2	8.7%	P. of cases: 11.1%
No. of Grazing Sheep (head)		Min: 4	Max:800	Mean: 130 Median: 68
Duration of grazing (month)		Min: 1	Max:3	Mean: 2.6
Who used fertilizer for barley?	No Yes	15 3		83% 17%
The number of times of using fertilizer per year?	3	Min: 1	Max:1	Mean:1

Source: Own elaboration from field survey (2020).

[1]*Marab is an ancient and simple concept: the floodplain levelling and dam and spillway-based intervention distributes excess runoff received from upland watershed areas, generated during erratic rainstorms, over the downstream flatlands, and thus enhances local water availability for enhanced crop production. ICARDA has been working to optimize this concept through advanced land suitability assessment and design considering diverse local environmental factors. The upgraded Marab layout allows for optimized water collection, deep infiltration and soil water storage for targeted field crop support – considering downstream water requirements – and, therefore, sustainably embedding the Marab agro-pastoral technology into basin water management. Locally, the Marab helps dryland farmers to extend growing windows, raise productivity, and reduce pressure on fragile resources.*

IV.3. Farmer's perceptions and attitudes towards the use of fertilizers/biosolids

The empirical findings on assessing farmers' perceptions and attitudes towards fertilizers and biosolids outlined in table 7 revealed that 100% of the respondents use fresh manure fertilizer. Besides, the results of the study also showed the following:

- About 95 % of respondents get the manure fertilizer from their own farm, and 5% buy fertilizer.
- Around 95 % of respondents didn't use chemical fertilizer, and 5% used chemical fertilizer.
- All 100 % of respondents didn't use treated animal manure fertilizer.
- All 100 % of respondents use fresh manure fertilizer.
- About 80 % of respondents feel satisfied with the existing fertilizer source (fresh manure), and 20% didn't feel satisfied.
- Almost 55 % of respondents heard about treated biosolids from several sources (i.e., NARC, Ministry of Agriculture, Ministry of Environment), and 45% didn't hear.
- All respondents didn't use treated biosolids before.
- Around 75 % of respondents have a negative perception of treated biosolids use in agriculture, and 25 % have a positive perception.
- 55 % of respondents have a positive perception of treated biosolids use to improve soil fertility of rangelands, and 45 % have a negative perception.
- 45% of respondents don't think that treated biosolids are a good alternative to existing resources, 25% don't know, 15% definitely not, 10% much, and 5% very much.
- 40 % of respondents don't think that treated biosolids is better than an available resource, 25% don't know, 20 % definitely not, 10% much, and 5% very much.

Table 7: Farmer's Perceptions - Farmers' Fertilizer use Patterns and Purchasing Behaviour

Survey Question	Answer	Frequency	Percentage %
What type of fertilizers used on your land?	Manure	20	100%
Where do you get the manure fertilizers?	Own Farm	19	95%
	Bought	1	5%
Did you use chemical fertilizers?	No	19	95%
	Yes	1	5%
Did you use treated animal manure?	No	20	100%
What type of manure used?	Fresh	20	100%
Are you satisfied with the existing sources of fertilizers?	No	4	20%
	Yes	16	80%
Did you hear about treated biosolids?	No	9	45%
	Yes	11	55%
Did you use treated biosolids before?	No	20	100%
What is your perception about treated biosolids use in agriculture?	Negative	15	75%
	Positive	5	25%
What is your perception about treated biosolids use to improve the soil fertility of rangelands?	Negative	9	45%
	Positive	11	55%
Do you think that treated biosolids are a good alternative to existing resources?	Definitely not	3	15%
	No	9	45%
	Do not know	5	25%
	Much	2	10%
	Very much	1	5%
Do you think that treated biosolids better than available resources?	Definitely not	4	20%
	No	8	40%
	Do not know	5	25%
	Much	2	10%
	Very much	1	5%

Source: Own elaboration from field survey (2020).

Regarding the farmers' willingness to use treated biosolids as organic fertilizer, the results indicated that most respondents (80%) will not use treated biosolids, while only 20% are willing to use treated biosolids (Table 8). Among the farmers who do not want to use treated biosolids:

- About 36% do not trust that biosolids suitability,
- Around 36% are concerned about using treated biosolids in the production of crops for human consumption.
- Almost 9% think that particular needs are associated with biosolids use,
- 9% of the respondents think that it is harmful to animals and then to humans (transfer disease),
- Around 5% mention that sheep don't graze on land treated with biosolids, and
- Finally, 5% of the respondents mention that it is not *Halal*[2]. and unclean because it is human waste.

On the other side of willing to use treated sludge as a soil improver in their agricultural land, the results indicated that 35% mention that definitely not, 25% no, 25% do not know, 10% much, and 5% very much. Sixteen farmers, 80%, didn't think that biosolids can be used for all crops, while 20% believed that it can be used for all crops.

For how much are they willing to pay for treated biosolids, 70% selected nothing, 15% will pay 1/4 the price of animal manure, the rest 5% of respondents will pay the same price as animal manure, 5% will pay half of the price of animal manure, and 5% don't know.

Using treated biosolids will affect the community's environmental situation as indicated by 70% think that it will have a negative effect, 25% believe that there is no effect on the environment, and 5% think it will positively affect (Table 8).

Table 8: Farmer's Perceptions _If you did not use treated biosolids before

Survey Question	Answer	Frequency	Percentage %
Are you willing to use it?	No	16	80%
	Yes	4	20%
if **No,** Because	Do not trust that biosolids are suitable	8	36.4%, P. of cases: 53.3%
	Concern about the use of the treated biosolids in the production of crops for human consumption	8	36.4%, P. of cases: 53.3%
	Special needs are associated with biosolids use	2	9.1%, P. of cases: 13.3%
	Harmful to animals and then to humans (transfer of diseases)	2	9.1%, P. of cases: 13.3%
	Because the sheep don't graze barely on land treated of biosolids	1	4.5 %, P. of cases: 6.7%
	Isn't Halal and Unclean because it is a human waste	1	4.5 %
Would you be willing to use treated biosolids as a soil improver for your agricultural land?	Definitely Not	7	35%
	No	5	25%
	Do Not Know	5	25%
	Much	2	10%
	Very Much	1	5%
Do you think treated	No	16	80%

[2]*"**Halal**" is an Arabic word meaning lawful or permitted. In reference to food, it is the dietary standard, as prescribed in the Qur'an (the Muslim scripture).*

biosolids can be used for all crops?	Yes	4	20%
How much are you willing to pay for treated biosolids?	The Same Price as Animal Manure	1	5%
	1/2 The Price of Animal Manure	1	5%
	1/4 The Price of Animal Manure	3	15%
	Nothing	14	70%
	Don't know	1	5%
How do you think using treated biosolids will affect the environmental situation in your community?	No effect	5	25%
	Negative effect	14	70%
	Positive effect	1	5%

Source: Own elaboration from field survey (2020).

IV.4. Factors influencing farmer's fertilizer purchasing decisions

Based on Likert scale results outlined in Table 9, the most critical factors influencing farmers' fertilizer purchasing decision were: the safety of fertilizer, nutrient content, organic matter, water holding capacity, recommended by a trusted source, volumes to apply, price of the fertilizer, fertilizer application and know someone who used it. Besides, there were less important factors influencing the farmer's fertilizer purchase decision: packaging, certification label, brand name, the product is locally made, and the product is imported. It was indicated the most unimportant factor for a farmer's decision is safety.

Table 9: Farmer's Perceptions - Factors influencing farmer's fertilizer purchasing decision

No.	Factors Influencing Farmer's Fertilizer Purchasing	Likert scale
1	Price of the fertilizer	Very influential
2	Nutrient content	Very influential
3	Organic matter	Very influential
4	Water-holding capacity	Very influential
5	Safety of fertilizer	Very influential
6	Packaging	Somewhat influential
7	Certification label	Somewhat influential
8	Brand name	Somewhat influential
9	Volumes to apply	Very influential
10	Fertilizer application	Very influential
11	Recommended by a trusted source	Very influential
12	Know someone who used it	Very influential
13	The product is locally made	Somewhat influential
14	Product is imported	Somewhat influential

Source: Own elaboration from field survey (2020).
Note: Likert scale ranking 1: not at all influential, 2: slightly influential, 3: somewhat influential, 4: very influential, 5: extremely influential

IV.5. Use of compost

The survey indicated that most (95%) used inorganic, and only 5% used chemical fertilizer. The survey revealed that about 60% of respondents didn't ask a reference authority about the suitable fertilizer, and 40% request a reference authority. Whereas 70% don't think that the agricultural extension gives adequate fertilization information, 30% believe that the agricultural

extension agents provide sufficient fertilization information. The study results revealed that 90% of respondents prefer organic fertilizer and 10% prefer chemical fertilizer. Also, 85% of the respondent can dispense chemical fertilizer, and 15% can dispense organic fertilizer (Table 10).

The study results also revealed that 90% of respondents used not fermented organic manure, and 10% used fermented organic manure. For those who used not fermented manure, 72% of respondents do not know the environmental restrictions and regulations for the use, and 28% know the environmental restrictions. Additionally, 50% of respondents know about the none fermented organic manure effect on the environment and know about the Rangers, and 50% have no idea. Survey results indicated that 90% of fermented or non-fermented manure sources from their farm and 10 % are mentioned by neighboring farms. When they produce fermented organic fertilizer, the survey indicated that 95% produce fertilizer from manure only and 5% produce fertilizer from plant residue. The survey indicated that 55% of respondents advise farmers to use manure and 25% advise farmers to use manure and plant residue, and 20% advise farmers to use plant residue.

When they know the manure advantage and features, the survey indicates that all farmers will use the fermented manure. Thus, in terms of thinking that fermented organic manure reduces desertification, the survey indicated that 85 % of respondents think it reduces desertification, 10% don't know, and 5% don't think. However, in terms of thinking that manure improves the water holding capacity and increase soil fertility, the survey indicated that 90% of respondent think it improves the water holding capacity and increase soil fertility and 10% Don't know. Finally, in terms of accepting manure mixed with biosolids, 80% of respondents refused manure mixed with biosolids, and 20% accepted (Table 10).

Table 10: Use of compost

Survey Question	Answer	Frequency	Percentage %
Type of fertilizer used	Inorganic	19	95%
	Chemical	1	5%
Do you ask the reference authority about suitable fertilizer?	Yes	8	40%
	No	12	60%
Do you think that the extension agents give adequate information about fertilization?	Yes	6	30%
	No	14	70%
The types of fertilizer you prefer	Organic	18	90%
	Chemical	2	10%
The types of fertilizer you can dispense	Organic	3	15%
	Chemical	17	85%
Type organic manure used	Fermented	2	10%
	Not fermented	18	90%
If the manure used is not fermented, do you know the environmental restrictions and regulations for the use?	Yes	5	28%
	No	13	72%
Have you an idea about the role of fermented organic manure environmental is pollution restriction?	Yes	10	50%
	No	10	50%
Source of fermented or non-fermented manure	From their farm	18	90%
	Neighbour's farms	2	10%
If you produce organic fertilizer, what type you make?	Plant residue	1	5%
	Manure	19	95
What is the best type of organic fertilizer you advise farmers to use?	Manure	11	55%
	Plant residue	4	20%
	Manure & Plant Residue	5	25%
If you don't have any idea about the fermented manure advantage and know its features, will you use it?	Yes	20	100%

Do you think that fermented organic manure reduces desertification?	Yes	17	85%
	No	1	5%
	Don't know	2	10%
If your land is a sandy soil texture, do you think that manure improves the water holding capacity and increases soil fertility?	Yes Don't know	18 2	90% 10%
Do you accept the use of other manufactures' manure, which manufactories from mixed biosolids?	Yes	4	20%
	No	16	80%

Source: Own elaboration from field survey (2020).

IV.6. Sources and preferences on the use of fertilizers

Regarding the suitable fertilizer, 75% of respondents asked the Ministry of Agriculture and NARC, 15% ask other farmers, and 10% ask private agricultural companies (Table 11).

Table 11: Sources on the use of fertilizers

Survey Question	Answer	Frequency	Percentage %
Who do you ask about suitable fertilizer?	Other farmers	3	15%
	Private Agricultural company	2	10%
	Ministry of Agriculture and NARC	15	75%

Source: Own elaboration from field survey (2020).

In terms of why you prefer to use chemical fertilizer, two respondents mentioned that the plant responds quickly to chemical fertilizers. In terms of the problems facing farmers when using chemical fertilizer, one respondent mentioned that it is harmful to plants and soil, and the other mentioned that it increases salinity. Whereas the solution from their point of view is natural fertilizers and compost, one respondent and the other mentioned that decreased quantity of chemical fertilizer (Table 12).

Table 12: Preferences on the use of chemical fertilizers

Survey Question	Answer	Frequency	Valid Percent	Percent
Why Do you prefer the use of chemical fertilizer?	The plant responds quickly to chemical fertilizers.	2	100%	10%
What are the problems facing farmers when using chemical fertilizer?	Harmful to plants and soil	1	50%	5%
	Increase salinity	1	50%	5%
What about your opinion (Solutions)?	Use natural fertilizers and compost	1	50%	5%
	Decrease quantity of chemical fertilizer	1	50%	5%

Source: Own elaboration from field survey (2020).

In terms of preferring the organic fertilizer, 60% of respondents mentioned increased productivity and improved product, 20% maintains the soil and conserve water, 10% use safe for health (not harmful), 10% available, and low cost. In terms of the problems facing farmers when using organic or non-organic fertilizer, 30% of respondents mentioned that It increases insects and worms, 30% mentioned they don't know how to make compost, 25% said bad smell, 15% said weeds appear. Whereas the solution from their point of view, 50% of respondents mentioned applying the fermentation, 30% said that experiment, 20% said that use pesticide (Table 13).

Table 13: Preferences on the use of organic fertilizers

Survey Question	Answer	Frequency	Percentage %
If you prefer (fermented or non-fermented) organic fertilizer, mention the reason?	Safe for health (not harmful)	2	10%
	Available and low cost	2	10%
	Increase productivity and improve product	12	60%
	Maintains the soil and conserve water	4	20%
What problems face farmers when they use organic fertilizer or non-organic fertilizer?	It increases insects and worms	6	30%
	Don't know how to make compost	6	30%
	Bad smell	5	25%
	Weeds appear	3	15%
What about your opinion? (solutions)	Do Experiment	6	30%
	Apply the fermentation	10	50%
	Use pesticide	4	20%

Source: Own elaboration from field survey (2020).

V. CONCLUSION AND RECOMMENDATIONS

This study is an effort to investigate farmers' perceptions of land application of treated biosolids on their farms/agro-pastoral communities. Surveys were conducted with randomly selected (20) farmers in the village of *Al Majeddyeh*. The survey questionnaire consisted of a mix of structured and open-ended questions.

The survey results indicate that most *Al Majeddyeh* farmers own a farm with less than 100 du. The major crops grown in the study area are barley, olive, and one respondent who cultivated vegetables mentioned that he cultivated around 2 du by Armenian cucumber and melon in *Marab*.

Overall, farmers' perception of land application of treated biosolids is negative, and the majority of the farmers don't want to use treated biosolids for several reasons:

- Do not trust that biosolids are suitable.
- Concerns about the use of treated biosolids in the production of crops for human consumption.
- Special needs are associated with biosolids used.
- It is harmful to animals and then to humans (transfer disease).
- Sheep don't graze on land treated with biosolids.

In terms of the most critical factors influencing farmers' fertilizer purchasing decision were: the safety of fertilizer, nutrient content, organic matter, water holding capacity, recommended by a trusted source, volumes to apply, price of the fertilizer, fertilizer application, and knowledge of someone who used it. The survey also revealed that all respondents didn't use treated biosolids before. Also, the majority of respondents pay nothing for treated biosolids. In terms of accepting manure mixed with biosolids, most respondents refused manure mixed with biosolids, and 20% accepted.

The findings from this study are valuable for Jordanian decision-makers in their roles to promote treated bio-solid sludge as fertilizers and soil conditioners. The Agriculture and Extension Services in the Agriculture Ministry should encourage farmers to use treated sludge (biosolid) in their community. This could be possible through the following measures:

i) Education of farmers through the launching of awareness programs about the benefits of treated biosolids and to improve farmers' perceptions on its land application;

ii) Providing farmers access to information (Technical, economic, regulatory, and institutional);
iii) Train farmers for the safe and effective use of treated biosolid;
iv) Raising public awareness by holding training workshops and conducting surveys about the efficient application of treated;
v) Continuing laboratory testing to identify possible impacts of sludge on their farmland and the environment.

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Personal information including Name, Business Title, Email, Phones, Images and GPS points included in this report have been authorized in writing or verbally by the data subject.

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Web-links

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ANNEXES

Annex I

Table 1. The main source of income

Source of income	Responses		Percentage of Cases
	N	Percentage	
Livestock	9	30.0%	45.0%
Crop's planting	9	30.0%	45.0%
Private business	4	13.3%	20.0%
Employment (labour)	2	6.7%	10.0%
Retirement	6	20.0%	30.0%
Total	**30**	**100.0%**	**150.0%**

Source: Own elaboration from field survey (2020).

Table 2. Employment status

Employment Status	Responses		Percentage of Cases
	N	Percentage	
Full- time Employment	4	13.8%	20.0%
Part - time Employment	3	10.3%	15.0%
Unemployment	1	3.4%	5.0%
Retired	6	20.7%	30.0%
Farm work	15	51.7%	75.0%
Total	**29**	**100.0%**	**145.0%**

Source: Own elaboration from field survey (2020).

Table 3. Uses of barley

Uses of Barley	Responses		Percentage of Cases
	N	Percentage	
Grazing	16	69.6%	88.9%
Harvesting	5	21.7%	27.8%
Selling before harvesting (crop lease)	2	8.7%	11.1%
Total	**23**	**100.0%**	**127.8%**

Source: Own elaboration from field survey (2020).

Table 4. Reasons for no using treated biosolids before

Reasons	Responses		Percentage of Cases
	N	Percentage	
Do not trust that biosolids are suitable	8	36.4%	53.3%
Concern about the use of treated biosolids in the production of crops for human consumption	8	36.4%	53.3%
Special needs are associated with biosolids use	2	9.1%	13.3%
Harmful to animals and then to humans (transfer of disease)	2	9.1%	13.3%
Because the sheep don't graze on barely that planted inland with biosolids	1	4.5%	6.7%
Isn't Halal and Unclean because it is a human waste	1	4.5%	6.7%
Total	**22**	**100.0%**	**146.7%**

Source: Own elaboration from field survey (2020).