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The Sustainability in Training Hydroponic Production to Smallholder Farmers in the Tshwane Area, Gauteng Province, South Africa

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ABSTRACT Smallholder farmers in the city of Tshwane Metropolitan were given three standard tunnels through comprehensive agricultural support programme to produce vegetables in a hydroponic system. This research sought to determine the sustainability in training hydroponic production to 38 smallholder farmers in the city of Tshwane. The objectives were as follows: (1) To describe socio-economic characteristics of the smallholder farmers, (2) To identify factors that contribute to the sustainability of smallholder farmers and, (3) To assess the effects of the hydroponic production training. The researchers used sustainability approach and Donald Kirkpatrick training evaluation model. The analysis found that most smallholder farmers were not sustainable, while they had increased their knowledge and skills in hydroponic production and their attitude had changed after the training. With regard to production, it was found that trained smallholder farmers increased production, increased quality of hydroponic produce, reduced waste and also increased sales. It can thus be concluded that smallholder farmers must be regularly trained and monitored to achieve the goals of sustainable development.

INTRODUCTION

Around 11 million South Africans are food insecure and it is estimated that a further 15 million in other Southern African countries (including Malawi, Zimbabwe, Namibia and Botswana) also go to bed hungry (Maponya et al. 2015). South Africa is largely deemed a food secure nation producing enough staple foods or having the capacity to import food, if needed in order to meet the basic nutritional requirements of its population but the same cannot be said about households. The Gauteng province is a home for over 12 272 263 peoples. According to GDARD (2010) almost twenty percent of households in Gauteng province go to bed hungry because of food insecurity and unsustainable income.

The term sustainability has been a centre of many farming principles. The interest of sustainability originates from the concept of sustainable agriculture, which can be traced back in the 1950-1960 (ATTRA 2003). Sustainability concept has dominated the policy making-arena hence today, concerns about sustainability centre on the need to improve agricultural practices that: (i) do not harm the environment, (ii) lead to food productivity, and (iii) are effective to farmers (Ainembabazi and Mugisha 2013). The components of sustainable agriculture can be broken into three: (i) economic, (ii) environmental, and (iii) social (ATTRA 2003). The implementation of sustainability is based on the mentioned components; firstly, the economic components consist of the yield increase, food safety and quality, farm diversity and market information. Secondly, the environmental component takes in soil fertility, water, energy, biodiversity and waste. Lastly, social components embrace human capital and local community (SAI 2009). Practicing sustainable agriculture can be done in any type of farming enterprise including hydroponic production.

Hydroponic production is defined as the science of growing plants without the use of soil. Sawdust, peat, vermiculite, gravel, and sand are used as growing mediums where essential elements are added as nutrient solution for plant growth and development. Advantages of hydroponic production system includes elimination of soil borne pest, weeds and diseases, less labour requirement and high density plant population in a limited space (Du Plooy et al. 2012).

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Hydroponics production has been acknowledged as a viable method of producing vegetables (DAFF 2013). However, the disadvantages of the system are linked to higher initial and operational cost, soil culture, appropriate skill and knowledge to operate the systems.

According to FAO (2015), hydroponic production is one of the methods that encourages urban agriculture, addresses poverty alleviation and job creation. It is in this context that smallholder farmers are encouraged to produce vegetables hydroponically. The research questions included:

(1) Which demographic information is available?
(2) Which factors do contribute to the sustainability of the smallholder farmers?
(3) How to assess the effects of the hydroponic production training?

The main aim of the study was to identify the effects of hydroponic production training on smallholder farmers in city of Tshwane Metropolitan Municipality (CTMM).

The specific objectives were:

(1) To describe socio-economic characteristics of the smallholder farmers.
(2) To identify factors that contribute to the sustainability of smallholder farmers.
(3) To assess the effects of the hydroponic production training.

Theoretical Background

Smallholder farmers play a crucial role in addressing food security and poverty alleviation (Dioula et al. 2013). Salami et al. (2010) defined smallholder farmers as "farmers with a plot size of less than five hectors and grow subsistence crops with the aim of tackling poverty and economic issues." Although there are various challenges that impede their growth and ability to effectively, contribute to food security. Some constraints they face relate to lack of skills (Dioula et al. 2013).

Skills development for smallholder farmers can be achieved through agricultural education and training (DAFF 2013). According to Davis et al. (2008) agricultural education and training is key to the development of human capital. The researchers emphasised that education enables the right for the realization of other economic, social and cultural rights. According to DAFF (2013) the number of smallholder farmers will increase from 200 000 to 500 000 by 2020. Supporting of smallholder farmers in terms of capital and training remain the main solution to boost productivity and sustainability to enable farmers to contribute to food security and job creation.

According to IFAD (2012), smallholder farmers around the world play a major role in food security and reducing poverty. However, challenges like production constraints, lack of investments, lack of comprehensive land policy, lack of storage equipment and postharvest processing as well as of applicable marketing systems, economic constraints, social constraints and environmental constraints impose threat to the sustainability of smallholder farmer (IFAD 2012). Training of smallholder farmers is aimed at capacitating them in order to address these challenges (FAO 2012). Maponya et al. (2016) also emphasized that smallholder farmers should be exposed to farmer training workshops which empowers them with technical skills and practical skills that improves their quality of produce.

The Gauteng Department of Agriculture and Rural development (GDARD) had assigned the Agricultural Research Council (ARC) as a service provider to conduct hydroponic trainings to small holder farmers in selected and designated regions (Germiston, Randfontein and Tshwane) of Gauteng province. However, the study concentrated only on the Tshwane region. The study complement studies conducted by other researchers and will promote sustainability in training hydroponic production to smallholder farmers in the city of Tshwane Municipality.

METHODOLOGY

A detailed questionnaire in English was developed for the data collection, and used both open and closed ended questions. Focus group discussions and field observations were also part of the data collection. Quantitative and qualitative methods and primary data source included information collected and processed directly by the researchers while secondary data source included information that the researchers retrieved through pre-existing source. The following data collection techniques were used: interviews, observations, questionnaires, previous research, official statistics, government reports, web information and historical data.

A purposive sampling technique was used to select 38 hydroponic agricultural projects out

of estimated 200 hydroponic projects in CTMM (see Fig.1). The sampling method was used to assess uniformity and homogenous characteristics like gender, age, racial group, educational level, years of farming, dependencies, economic sustainability, social sustainability, environmental sustainability, production sustainability, production challenges, reaction about the training received, knowledge gain from the training, behavioural change after the training and the outcomes of training. The descriptive analysis was conducted using Statistical Package for the Social Sciences (SPSS) programme. The descriptive analysis was conducted to identify frequencies, percentages, means, and modes of the variables.

Model Used for Analysis

Two models were used to analyse data, namely: (1) The Sustainability concept and (2) Kirkpatrick's evaluation model.

Sustainability Approach

Sustainability concept is known as the concept that promotes meeting the needs of the present without compromising the ability of future generations to meet their own needs. The concept stands on three pillars namely: environmental, economic, and social sustainability. Sustainability concept was used to determine the sustainability in training hydroponic production to smallholder farmers in the CTMM. Sustainability concept is useful in analysing data where the researcher is interested in finding the prospect of a farm being profitable.

Kirkpatrick's Evaluation Model

Kirkpatrick's evaluation models allowed assessment of trainee to view training impact.

The Kirkpatrick methodology was used to assess the effects of training hydroponic production to smallholder farmers in the CTMM. A typical Kirkpatrick's evaluation models was used in the form of :

a) Reaction: The trainee's impression of the administration.
b) Learning: The acquisition of knowledge, skills and attitudes (KSA) from the training.
c) Application: The performance of the trainee on the farm following the application of KSA.

Fig. 1. City of Tshwane Map

d) Results: Changes that the trainee's performance brought to the farm. Change was measured against the performance before intervention or training.

RESULTS AND DISCUSSION

Demographics

Table 1 summarised the gender of the 38 smallholder who attended hydroponic training from the city of Tshwane Metropolitan Municipality (CTMM), this revealed that 57.9 percent were Male and 42.1 percent were female. This highlighted that male farmers in the city of Tshwane Metropolitan Municipality were mostly involved in hydroponic production. It also showed that gender gaps existed between male and female, which implied that any developmental strategy for the farmers in the area would not benefit both females and males almost equally.

Table 1: Gender of respondents

	Frequency	*Percent (%)*
Male	22	57.9
Female	16	42.1
Total	38	100.0

Age of the hydroponic farmers is important in view of sustainability of the farm and agricultural sector as the whole. The results in Table 2 indicated the age of the respondents. There is youth and adult interest in hydroponics in the city of Tshwane Metropolitan Municipality. As only 23.7 percent of youth (21-35 years) is participating in hydroponics, and 76.3 percent of farmers fall under other categories. According to IFAD (2012), youth participation in agricultural training is encouraged to meet the country's agricultural challenges and sustainability. Any future hydroponic development in the CTMM should be designed in such a way that it attract young people's interest.

Table 2: Age of the respondents

	Frequency	*Percent (%)*
21-25	2	5.3
26-30	3	7.9
31-35	4	10.5
36-40	3	7.9
41-50	10	26.3
51-60	8	21.1
61 or older	8	21.1
Total	38	100.0

Table 3 showed that the racial group of the respondent is hundred percent black African which indicated the commitment that GDARD made in terms of empowering black smallholder farmers in Gauteng Province (GDARD 2010).

Table 3: Racial group of the respondent

	Frequency	*Percent (%)*
African/Black	38	100.0

The results in Table 4 indicated that there is difference in education level of respondents. Most respondents were credible to have formal education, only 2.6 percent had never been to school, and 97.4 percent had an opportunity to obtain formal qualification ranging from grade 8 to tertiary qualification. These results indicated that educational levels of CTMM smallholder farmers is generally adequate to enable interpretation and understanding of basic hydroponic production practices and principles. Some smallholder farmers who had achieved tertiary education are expected to understand and appreciate hydroponic production better than those who had less education level. The lower educational levels among the trained smallholder farmers implied that training of hydroponic production might be of minimal benefit to such farmers.

Table 4: The highest level of education that respondent holds

Valid	*Frequency*	*Percent (%)*
Never been to school	1	2.6
Grade R to grade 8	7	18.4
Grade 9 to grade 12	12	31.6
Matriculated	8	21.1
National certificate	5	13.2
Tertiary qualification	5	13.2
Total	38	100.0

Farming experience is crucial when practicing hydroponic, this is due to the level of technical skills required to operate the systems. Experienced smallholder farmers are able to adopt to new technologies and become sustainable. The results in Table 5, presented the number of years in which respondents were involved in farming. Only 31.6 percent had less than 5 years'

experience in hydroponic farming, and 68.4 percent had more than five years of experience.

Table 5: Respondents number of years in farming

	Frequency	*Percent (%)*
Less than 5 years	12	31.6
More than 5 years, but less than 10 years	14	36.8
More than 10 years, but less than 20 years	10	26.3
More than 20 years	2	5.3
Total	38	100.0

Table 6 summarized the number of dependencies to the respondent. Only 84.2 percent (32 dependants) indicated that they have people who depend on them for their livelihood while 15.8 percent (6 non-dependants) had no dependencies.

Table 6: The number of dependencies of the respondent

Valid	*Frequency*	*Percent (%)*
Yes	32	84.2
No	6	15.8
Total	38	100.0

Economic Sustainability of Smallholder Farmers

Economic sustainability of hydroponic smallholder farmers is essential for maintaining farm operations, as the farm has to be economically viable. Table 7 showed that seventy-eight percent of respondents were consistently experiencing net worth problems while twenty-two percent of respondents net worth is consistently going up, similarly, sixty-two percent of respondents had debt challenges while thirty-eight percent of respondents family debt is consistently going down. This is evident as seventy percent of respondents were not profitable from year to year, and only thirty percent of respondents were consistently profitable from year to year. However, as per operational costs like electricity and water most respondents (61%) can afford to pay on monthly basis while thirty-nine percent of respondents are struggling to pay electricity and water. As per Table 7, twenty-two percent of respondents relied on government payments while seventy-eight percent of respondents do not rely on government payments. These indicated that economic sustainability is a challenge that needs to be addressed as soon as possible.

Table 7: Economic sustainability of smallholder farmers

Economic sustainability	*Yes (%)*	*No (%)*
Is the family savings or net worth consistently going up?	22	78
Is the family debt consistently going down?	38	62
Is the farm enterprises consistently profitable from year to year?	30	70
Is the farm able to pay electricity and water?	61	39
Does the farm rely on government payments?	22	78

Social Sustainability of Smallholder Farmers

Social sustainability of smallholder farmers is needed to retain the trust of the community within which the farm operates. The results in Table 8 indicated that eighty-seven percent of respondents support other businesses and families in the community, while thirteen percent do not support other businesses and families in the community. The evidence of these is based on ninety-two percent of respondents who accepted that the rand circulate within the local economy as they sell their produce to local businesses and families, while eight percent of respondents sell to the foreign businesses. Similarly, ninety-two percent of respondents received mutual support within the family while eight percent lack support within the family. However, the farms are to continue to make impact as seventy-three percent of respondents believed that young people would take over their parents' farms and continue farming, while twenty-seven percent of respondents are doubtful. This is evident as fifty-four percent of respondents indicated that college graduates return to the community and continue farming while forty-six percent of respondents did not experience college graduates returning to the community. These results submit that smallholder farmers do contribute socially to the community and young people should be encouraged to return to their community after graduating and continue farm.

Table 8: Social sustainability of smallholder farmers

Social sustainability	*Yes (%)*	*No (%)*
Does the farm supports other businesses and families in the community?	87	13
Does the rand circulate within the local economy?	92	8
Is there mutual support within the family?	92	8
Does young people take over their parents' farms and continue farming?	73	27
Do college graduates return to the community after graduation?	54	46

Environmental Sustainability of Smallholder Farmers

Environmental sustainability of smallholder farmers is necessary to conserve and preserve the natural resources. Table 9 showed that environment is not affected by the farming operations of respondents. About eighty-seven percent of respondents maintain their soil fertility, while thirteen percent of respondents do not maintain their soil. This is because hydroponics is a system of growing crops without soil. However, water is a scarce resource, these became prevalent when forty percent of respondents had sustainable irrigation system, while sixty percent of respondents said water source for irrigation is not sustainable.

Table 9: Environmental sustainability of hydroponic projects

Social sustainability	*Yes (%)*	*No (%)*
Is the soil fertility maintained that is, measured by conducting of soil tests?	87	13
Is the water source for irrigation sustainable?	40	60
Is the biodiversity threatened by growing the crop?	14	86
Is the energy source impact on climate change?	5	95
Is the waste managed correctly?	84	16

Meanwhile, biodiversity in not threatened as much, only fourteen percent of respondents observed a threat of biodiversity while eighty-six percent respondents do not think biodiversity is threatened. About ninety-five percent of the respondents interviewed said their energy source does not impact on climate, while five percent of respondents said their energy source impact on climate. And eighty-four percent of respondents interviewed said they managed their waste correctly, while sixteen percent of respondents indicated that their waste is not managed correctly. This is clear indication that environment in CTMM is not threatened by hydroponic production. It is interesting to note that most hydroponic smallholder farmers in CTMM understand principles of recycling, reuse and dispose.

Effects of the Hydroponic Production Training

Sustainability of hydroponic farms are critical in a city of Tshwane municipality as hydroponic farming can help in job creation and food security. A total number of 38 smallholder farmers who attended one week accredited hydroponic production training at Agricultural Research Council, Vegetable, Ornamental Plant (ARC-VOP) in Roodeplaat were interviewed to assess the effects. The impact of training is worth observing to identify the gaps and challenges to assist smallholder farmers to become productive and sustainable under any adverse conditions. Training evaluation model of Donald Kirkpatrick was used to assess the effects of hydroponic production training. Four levels of assessment was used namely: Reaction level, Learning level, Application level and Results level (Kirkpatrick and Kirkpatrick 2006).

Reaction Level

The reaction level seek to determine the level of satisfaction, needs and displeasure about the hydroponic training (Kirkpatrick and Kirkpatrick 2006). As indicated in Table 10, about ninety-seven percent interviewed responded think that the training was successful, and eighty-two percent of respondents identified practical activities as the strength of the training. Despite forty-three percent of respondents who indicated that discussions were the biggest weakness of the training, only eighty-four percent of respondents said the venue was good, while ninety-seven percent of respondents indicated that their style of learning was accommodated during training. It is interesting to note that the level of satisfaction with the training

Table 10: Reaction level

Reaction			
Thoughts about the training?	*Successful (%)*	*Not successful (%)*	
	97	3	
The biggest strengths of the training?	*Theory (%)*	*Practical (%)*	*Discussions (%)*
	13	82	5
The biggest weaknesses of the training?	*Theory (%)*	*Practical (%)*	*Discussions (%)*
	41	16	43
Feelings about the venue?	*Good (%)*	*Fair (%)*	*Poor (%)*
	84	11	5
Did the training session accommodate your needs?	*Yes (%)*		*No (%)*
	97		3

course provided is impressive and it worth appreciated by the ARC-VOP. Despite the different level of education background farmers were able to understand and enjoy training which was presented in English.

Learning Level

The learning level seek to determine acquisition of knowledge, skills and attitudes from the hydroponic training program (Kirkpatrick and Kirkpatrick 2006). As seen in Table 11, only fifty-two percent of respondents identified growth media for hydroponic system as a topic which increased their knowledge and skills, followed by twenty-three percent of respondents who identified pH and EC for hydroponic and thirteen percent of respondents identified nutrients solution for hydroponic and twelve percent of respondents identified structure for hydroponic crops.

Besides the main topics, which were covered on the hydroponic training module, twenty percent of respondents listed the following topics: marketing, planting of crops, and scouting of pest, weeds and diseases as topic that increased their knowledge and skills. The results showed that acquisition of knowledge, skills and attitudes from the hydroponic training were critical for sustainability of hydroponic production. Smallholder farmers indicated that they have gained a lot of experience.

Application Level

The application level seek to understand the performance of the trainee and whether skills, knowledge and attitudes acquired during hydroponic training is applied on the farm (Kirkpatrick and Kirkpatrick 2006). Table 12 showed the application level of respondent, about ninety percent of respondents indicated that they have applied their learning to use, while ten percent of respondents were not able to apply their knowledge, this was found that respondents did not practice farming after the training till to date. Nevertheless, respondents indicated that they

Table 12: Application level

Question	*Reply*	
	Yes (%)	*No (%)*
Did you apply any of your learning to use?	90	10
Are you able to teach your new knowledge, skills, or attitudes to other people?	100	0
Are you aware that your behaviour has changed?	100	0

Table 11: Learning level

Question	*Reply*	*Percent (%)*
Selecting a Topic which has Increased your Knowledge and Skills?	Growing media for hydroponic systems	52
	Nutrient solutions for hydroponic crops	13
	PH and EC for hydroponic crops	23
	Structures for hydroponic crops	12
Other Topics	Marketing	20
	Pest control	20
	Planting of crops	20
	Scouting pests, weeds and diseases	20

are able to teach new knowledge, skills, or attitudes to other people and they have changed their behaviour, which received hundred percent respectively. Application of theories in agriculture specifically for hydroponic training is useful to the development of smallholder farmers. It must be emphasised that data was collected after six months of training to enable farmers to apply knowledge gained through the trainings.

Results Level

The results level seeks to determine whether some improvements and changes were obtained through the application of skills, knowledge and new attitude about the acquired hydroponic training in the farming environment (Kirkpatrick and Kirkpatrick 2006). Table 13 summarised the results of the hydroponic training to smallholder farmers in Tshwane. About forty-four percent of respondents increased their productivity, while forty-one percent of respondents increased quality. On the other hand, nine percent of respondents reduced waste, while six percent increased sales. These results highlighted the importance of hydroponic training and its impact on the smallholder farmers. As a result, the sustainability of smallholder farmers could be linked with the positive results of the hydroponic training. Monitoring and evaluation of farmers and their opinion were used to measure the results of training.

Table 13: Results level

Question	*Reply*	*Percent (%)*
The Results of the Training?	Increased production	44
	Increased quality	41
	Reduced waste	9
	Increased sales	6

CONCLUSION

The main objective of the study was to check the sustainability in training hydroponic production to smallholder farmers in the Tshwane area of Gauteng province in South Africa. From this study, it has been found that factors such as gender, age and level of education have a positive effect on the sustainability of hydroponic farming. The study found that most hydroponic smallholder farmers were not sustainable. It has been noticed that socially, hydroponic smallholder farmers support other business around the community by selling their produce and there is also mutual support in most hydroponic smallholder farmers, where even young people who went to school were willing to take over their parents farms and continue. These showed signs of social sustainability. It was also noted that environmentally, most hydroponic smallholder farmers were able to maintain biodiversity on their farms and climate is not impacted negatively. However, the study showed that economically hydroponic smallholder farmers were not sustainable. This was evident when most hydroponic smallholder farmers were not profitable from year to year while their net worth and family debt were consistently showing a dire stress.

The study has analysed the response of smallholder farmers towards hydroponic production training. It was noted during the survey that hydroponic smallholder farmers responded positively to the training of hydroponic production as most famers enjoyed the practical demonstrations. It is also interesting to note that hydroponic production learning was fruitful to most hydroponic smallholder farmers. It was noted that the application of hydroponic training has changed the attitude of hydroponic smallholder farmers, as they were able to apply the skills and knowledge of hydroponic production and continue to teach others. The results of this study were clear that hydroponic training has increased production of hydroponic produce, increased quality of hydroponic produce, reduced waste and increased sales of the trained hydroponic farmers in city of Tshwane Metropolitan Municipality.

RECOMMENDATIONS

It is thus recommended that hydroponic production of vegetables in city of Tshwane Metropolitan Municipality should be encouraged to smallholder farmers. It is recommended that youth and woman empowerment should be promoted through participation of sustainable agricultural activities. It can thus be concluded that smallholder farmers must be regularly trained and monitored to achieve the goals of sustainable development.

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