CREATING AGRIBUSINESS OPPORTUNITIES FOR SMALL SCALE FARMERS IN THABA NCHU BY INTRODUCING WATER HARVESTING TECHNIQUES: A PROFITABILITY AND RISK ANALYSIS

by

M. Baiphethi, M. F. Viljoen and G. Kundhlande

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Creating Agribusiness Opportunities for small scale farmers in Thaba Nchu by introducing water harvesting techniques: A profitability and risk analysis

M Baiphethi, M F Viljoen and G Kundhlande, University of the Free State

Abstract

Thaba Nchu is a semi-arid area with low and erratic annual rainfall not exceeding 600mm. Various dryland crops are produced with relatively low yields and high risk of failure. Lack of appropriate technology and other constraints has led to most of the arable land being unused thus restricting agribusiness opportunities in an area where unemployment and food insecurity are thriving.

Rainwater harvesting has a huge potential to increase crop yields in Thaba Nchu and reduce the risk of losses, and thus improve food security and enhance sustainability. Different in-field rainwater harvesting (IRWH) techniques have been tested and applied at Glen and Thaba Nchu. This paper gives comparative results for three crops produced with regard to relative profitability and risk of failure. This is done by integrating crop enterprise budgets with crop yield simulations models to calculate per hectare profits over an 81-year period and developing and analyzing cumulative probability functions.

1. Introduction

It is generally agreed that food production increases will to a great extent come from "improved productivity per unit water and soil" (Hofwegen van and Svendsen, 2000). However, sub-Saharan Africa has an estimated 41% of its present agricultural land located in semi-arid regions, with a small proportion under some form of irrigation. This implies that rainfed agriculture will, for a foreseeable future, be the dominating source of food for an increasing population in these areas (FAO, 1990 and Parr et al., 1990). As a result there is need for more efficient use of water in both rainfed and irrigated agriculture to meet future food demand and growing competition for water (Fox & Rockstrom, 2003). These challenges are the same for the Thaba Nchu area in the Free State Province where a large area of land, in an effort to improve livelihoods, has been earmarked for developing farmers. The area experiences low crop production due to marginal and erratic rainfall, which is exacerbated by high runoff and evaporation losses (Hensley et al., 2000). Measures which can be used to ameliorate these constraints include rainfall conservation, reduction of irrigation water losses and adoption of cultural practices (Smith, 2000). It has been shown that significant gains in crop productivity in rainfed agriculture may originate from small scale harvesting of water. For maize and sunflower, in the study area, indications are that IRWH has the potential to increase yields by about fifty percent (50%) in the long term compared to conventional tillage (CON).

Even though significant gains in crop productivity can be made by the use of IRWH, unreliable and very often low and insufficient cumulative rainfall are inherent characteristics of the Thaba Nchu area. Characteristic of semi-arid areas, the primary limiting factor for crop yield stabilization is the amount of crop water available in the rootzone during the growth stages of a crop. However, low annual or seasonal rainfall may not necessarily be the critical constraint in crop production but the irregular occurrence of rainfall events often are (Sivakumar and Wallace, 1991). This is argued by some to be the explanation for the large yield gap in dryland farming systems where recurrent water scarcity erodes yield potential and in addition soil nutrient deficiency is more limiting to crop growth than water due to its impact on water uptake capacity (Smith, 2000). According to Fox and Rockstrom (2003), water and nutrients interact in limiting crop growth and thereby need to be addressed together in efforts of improving crop yields.

The factors discussed above either individually or collectively result in low yields for farmers in semi-arid areas and become important causes of low profits and uncertainty and risks for farmers in the Thaba Nchu area. This tends to discourage more intensive small-scale agriculture but it has been shown that IRWH will increase returns and reduce risk significantly compared to conventional tillage.

This paper presents a profit and risk analysis of IRWH for small-scale resource poor farmers in the Thaba Nchu area, east of Bloemfontein for three crops; dry beans, maize and sunflower. Results are presented on economic performance, with a special emphasis on farm profits and risk, with the view to ultimately determine the best water harvesting technique for farmers in the study area.

The rest of the paper is structured as follows: section 2 provides a description of the study area followed by a discussion of the water harvesting techniques under study in the third section. Section four outlines the materials and methods used, empirical results are presented in the fifth section and the conclusions and recommendations are made in the sixth section.

2. The study area

The study uses data from an on-station experiment at Glen Research Station and also on-farm data from villages in Thaba Nchu. The experimental station is located 30 km north east of Bloemfontein along the R30 road. The long term mean rainfall for the area is 545 mm. The high evaporative demand and relatively low rainfall make this a semi-arid area (Hensley et al., 2000). The worst conditions for crop production occur during December, January and February with very erratic rainfall and much of it occurring in a few high intensity rainfall events. March rainfall is the highest and most reliable and during this month there is the lowest evaporative demand. The soil is a dark brown clay soil overlying $CaCO_3$ enriched sandstone saprolite at a depth of 800 mm (Hensley et al., 2000). The soil has a strong structure and high content of smectite clay minerals which cause large cracks that penetrate deep into the soil when it is dry. In addition the soil has a high water holding capacity in the rootzone.

Thaba Nchu is located 58 km east of Bloemfontein and was formerly part of the Bophuthatswana homeland. There is a large population living in 42 villages around the town of Thaba Nchu. Low rainfall and high evaporation coupled with poor soils are major constraints to crop production in the Thaba Nchu agricultural district. The area is characterized as a semi-arid area with low and erratic annual rainfall not exceeding 600mm per annum (Hensley et al., 2000). While the average long-term annual rainfall may seem adequate to support the production of dryland crops, the intensities and distribution are such that the water available during the crop growth cycle is inadequate to support a good harvest. In addition the soils are predominantly clay on which the precipitation use efficiency is low due to high water losses to runoff and evaporation from the soil surface. As a result the area is marginal for crop production.

Currently land is one of the readily available productive assets for households in the Thaba Nchu area. Each household in the area has access to about 2 to 4 ha of arable land. In addition the households have 0.2 ha-homestead land, part of which they can use to produce crops in homestead gardens. The communities also have communal pastures for their livestock - mostly sheep, cattle and horses. However, most of the arable land remains unused in part due to lack of appropriate production technologies, low returns from production and other constraints. Some of the arable land has not been put to cultivation for the last three to five years or even more. The land needs to be put into production so as to increase the food supply for the farm households and perhaps generate additional income. The main crops that farmers grow in their fields are maize, wheat and sunflower. The other crops grown are potatoes, sorghum and dry beans. Currently these crops are mainly grown in homestead gardens. Households also grow some vegetable crops like spinach, pumpkins and onions. Production of most crops is largely geared towards household consumption with any surplus being sold to other villagers.

3. Water Harvesting

Water harvesting refers to different methods where surface runoff is collected and stored in dams, tanks, or cisterns, for later use (Hudson, 1987). Although literature suggests that there is no clear-cut classification of water harvesting methods as different authors have used different classifications, there are some commonly used classifications of the methods and techniques of water harvesting. One method of water harvesting that is primarily used for crop production is called Mini-Catchment-Runoff Farming (MNCRF) (Oweis et al., 1999). Boers and Ben-Asher (1982) refer to the same method as Runoff Farming Water Harvesting (RFWH), which they define as a method of collecting surface runoff from a catchment area and storing it in a surface reservoir or in the rootzone of a farmed area for direct consumptive use. For this method the runoff producing catchment is a long strip and the water from the catchment is collected directly into the cropped area. The catchment usually receives an appropriate treatment regarding the shape, configuration, surface condition, and runoff inducement practices. The water harvesting techniques in the study fall within the MNCRF category and are called the in-field water harvesting techniques (IRWH) as their emphasis is on the collection of in-field runoff and its storage in the soil profile to support plant growth.

Six variations of the Agricultural Research Council's Institute for Soil, Climate and Water (ARC-ISCW)'s IRWH techniques are analyzed in this paper. The six variations were selected based on their promise for best results in terms of yield increase. One variation of the IRWH techniques is the use of organic mulch in the basins and a bare runoff strip (MB) (Botha et al., 2001). Under this system rainwater falls on the runoff strip and then it flows down the slope into the basin where it is collected and stored in the rootzone for use by crops during the growing period. Organic mulch from either crop residue (eg. maize stalks) from the previous season or grasses is applied in the basins. The mulch helps reduce evaporation. The runoff strip is left bare to enhance runoff into the basins. The other variations of the IRWH techniques examined here involve the different configurations of organic and stone mulches in the system. One such is the use of stone mulch in both the runoff strip and the basins (SS). The other alternatives are the variations in the use of both organic mulch and stone mulch; i) stone mulch in the basins and organic mulch on the run off strip (SM), ii) organic mulch in the basins and stone mulch on the runoff strip (MS), iii) organic mulch on the basins and runoff strip (MM), and iv) no mulch on the basins nor runoff strip (BB), ie, both the runoff strip and basins are not covered with any form of mulch. In all cases it is recommended that the runoff strip and basins must be kept free of weeds at all times so as to limit non-productive transpiration.

Water harvesting techniques, however, represent changes to the traditional way of growing crops, as they may entail some extra work and different ways of performing the same tasks. For these and other reasons, there is a need to study the financial/economic potential of IRWH even though their potential to increase crop yields has been demonstrated.

4. Materials and Methods

i) Data

Production data for the analysis were obtained from on station and on farm production trials conducted by the ARC-ISCW (Glen) in collaboration with the University of the Free State, Department of Agricultural Economics. On-farm trials were in three selected villages around Thaba Nchu and on-station trials were at the Glen research station. The trials provided production data from which enterprise budgets were estimated for each crop and production technique. On-station trials have been going on for three years (1999/2000, 2000/2001 and 2001/2002) while the on-farm trials were conducted during the 2001/2002-production season. Of the six IRWH techniques, only one was employed in the on-farm trials, the BB variation and the rest of the techniques were employed on the on-station plots. Data was collected in terms of the daily activities performed on the trials. The records included the planting date, type and quantity of inputs used. These data are used to estimate enterprise budgets (ha^{-1}) for each crop and production technique.

Secondly, yield data was simulated for the study area using the CYP-SA[1] crop model. The simulations were based on rainfall data for the past 81 years in the area and the yield data was linked to the estimated crop enterprise budgets to determine the gross margins (R ha^{-1}) for the same period. The calculated gross margins were then used to estimate cumulative distribution functions.

ii) Estimation of Cumulative Distribution Functions

Since on-farm experimental trials are not often conducted for a period more than three or four years, the exact distribution of outcomes are not known, therefore must estimated (Langyintuo et al, 2002). A simple empirical method for the estimation of outcomes for such multi-year on-farm trails was proposed by Hein et al (1997). The method of estimation depends on the objective of the analysis in addition to the number of observations and type of information available. The basic assumption of

[1] Rainfall data for the past 81 years used in CYP-SA to predict yields for each year in that period. The predicted yields were linked to an enterprise budget to determine the gross margin for that year.

the method is that farmers' fields on which the trials were conducted are representative of the farming community.

The probability of each outcome/observation, *i,* in year *t*, (P_{it}), is estimated using the relationship: (P_{it}) = (1/T), where T is the number of cropping seasons. It was assumed that each gross margin has an equal chance of occurring anytime during the 81-year period. The gross margin data was ranked in ascending order and then assigned probabilities. The cumulative probability of an observation was calculated as probability of the observation plus the sum of the probabilities ranked below it. Each observation and its cumulative probability were graphed and the points were connected with linear segments to generate a cumulative distribution function.

iii) Comparing Cumulative Distribution Functions

In comparing the CDFs, stochastic dominance analysis was used due mainly to its reliance on simple, intuitive observations on farmer behaviour (Langyintuo et al., 2002). Two stochastic dominance rules were used being the first order stochastic dominance (FSD) and second order stochastic dominance (SSD). The first order stochastic dominance rule assumes that farm operators prefer more to less of an outcome. This implies that if the cumulative probability of an alternative is greater than the cumulative probability of another alternative for all outcome levels, then the alternative with the higher probability is dominated by the alternative with the lower probability (Anderson and Dillon, 1992 and Hardaker et al., 1997). The alternative in our case is the production technique, eg BB. The second rule is applicable when the cumulative distribution functions of two alternatives cross and thus FSD cannot be used. Statistically, the area under the cumulative distribution curve reflects the tendency for an alternative to have low value outcomes. This implies that for a given level of outcome, the choice with the greatest area under the CDF has the highest probability of low value results.

The profitability of the techniques was measured by the gross margin determined from the enterprise budgets developed and compared to the conventional production techniques while risk was measured using the cumulative probability functions and their comparison by stochastic dominance.

5. Results and Discussion

The results are discussed in two parts: the profit analysis and the risk analysis. Profit analysis is done using the gross margins (R ha^{-1}) from production. Risk analysis is done with the aid of CDFs and their comparison using stochastic dominance.

i) Profit analysis

Table 1 shows the gross margin (R ha^{-1}) for the production techniques in three villages and the experimental site for maize, sunflower and dry beans during the 2001/2002-production season. The villages on which on-farm trials were performed are Feloane, Paradys and Yoxford , the table also shows the same data for on-station trials in Glen.

It is evident from the table 1 that considerable increases in gross margins from production are obtained by using the IRWH techniques as opposed to CON. In Feloane, BB resulted in higher gross margins than CON for all the crops. In the case of sunflower, CON had a negative gross margin(GM) of R549.67 whereas BB resulted in a GM of R1117.77. Dry beans also gave significant increases in GM for BB of R3221.57 compared to R523.68 from CON. The same trend is also seen in the other two villages even though only one crop was grown in each village.

For on-station trials, IRWH techniques resulted also in better returns than CON. For all the crops, the greatest improvements were achieved by moving from CON to IRWH as shown by the differences in GM between CON and BB, the least productive of the IRWH techniques. The production of maize under CON gave a gross margin of R1168.00 compared to BB's R2674.00. The highest GM (R3866.00) was achieved with the MS technique followed closely by SS at R3852.00. Sunflower production also shows the same trend as maize with the highest GM attained from the SS technique, and as expected there is great leap from CON (R656.00) to BB (R1489.00). However, unlike maize, the SS technique produced the highest GM for sunflower. In the case of dry beans, there is also a substantial increase in GM from CON to BB and the highest increase is from MS as was the case with maize. The results imply that there would be increases in profits brought about by the use of IRWH techniques in farmers' fields. This will go a long way in encouraging farmers to take up farming as there are better returns brought about by IRWH techniques. The situation will encourage the emergence of agribusinesses and thus creation of jobs in the area as crop farming will a profitable.

Table 1: Gross margins per hectare (R ha^{-1}) for different production techniques for on-station and on-farm trials during the 2001/2002-production season

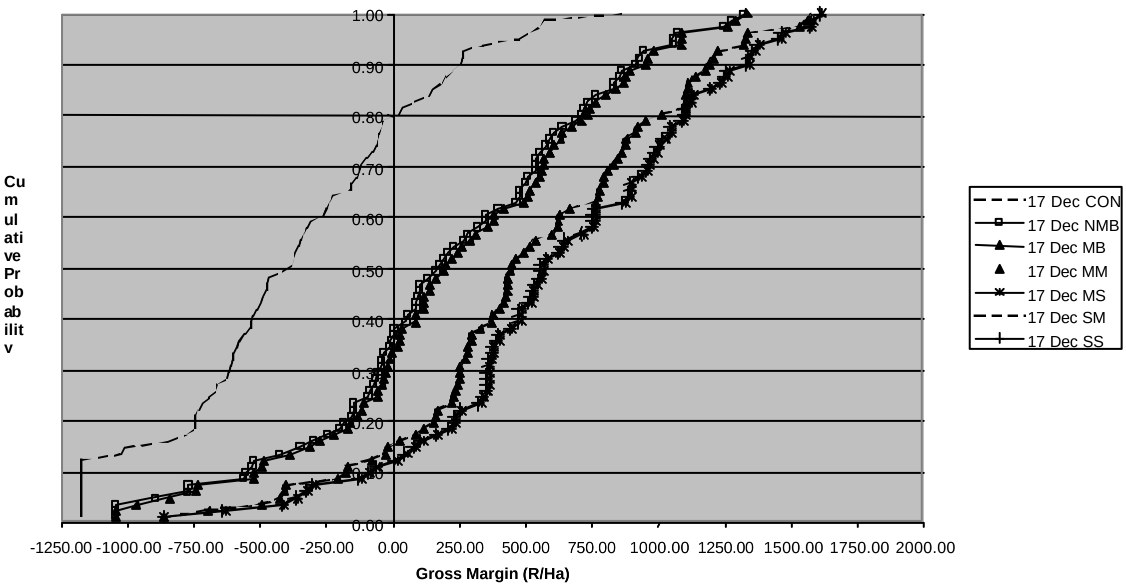
Place Production Techniques	Maize	Sunflower	Dry beans
Feloane (On-farm trials)			
CON	277.00	-550.00	524.00
BB	946.00	1118.00	3222.00
Paradys			
CON	-	-44.00	-
BB	-	360.00	-
Yoxford			
CON	-271.00	-	-
BB	1261.00	-	-
Glen (On-station trials)			
CON	1168.00	656.00	95.00
BB	2674.00	1489.00	1124.00
MB	2674.00	1591.00	1308.00
MM	3834.00	1311.00	1560.00
MS	3866.00	1603.00	1576.00
SM	3834.00	1528.00	1560.00
SS	3852.00	1684.00	1570.00

ii) Risk analysis

Enterprise budgets for three crops (sunflower, maize and dry beans) under IRWH techniques in the study area were linked to yield data attained with the CYP-SA for an 81-year period and gross margins (R ha^{-1}) were calculated. The gross margins are presented in cumulative probability function format for each crop. The results are aimed at drawing comparison between CON and IRWH techniques in order to make some recommendations on crop production practices in the study area.

Cumulative probability distribution functions based on gross margins (R ha^{-1}) for

Figure 1: Cumulative probability distribution functions based on gross margins for maize over the the past 81 years (1923-2003) in the study area



maize for an 81-year period are reported in figure 1. CON lies to the left of all the IRWH techniques and hence is first order stochastically dominated (FSD) by the IRWH techniques. The CON CDF shows that about 80 % of the time, the technique will yield gross margins less or equal to zero implying higher risk associated with CON production of maize in the study area as opposed to the use of IRWH techniques. This means that there is a higher chance of crop failure when using conventional production technique and this is true since most farmers have stopped crop farming mainly due to crop failure. The least productive IRWH technique, BB has about 36 % chance of yielding a gross margin of zero or less. This is considerably different from the CON technique. This shows that major gains are made by moving from CON to IRWH as table 1 has already shown. This is further shown by the differences in improvement between BB and MB, MM and SM and finally MS and SS. The differences between these pairs of water harvesting techniques are not as huge as that between CON and BB. MS is first order stochastically dominant to all the other techniques. MS has a less than 12 % chance of the getting zero or less returns as opposed to about 80 % when conventional production is used.

Figure 2: Cumulative distribution functions based on gross margins (R/Ha) for sunflower for different production techniques for the past 81 years (1923-2003) in the study area

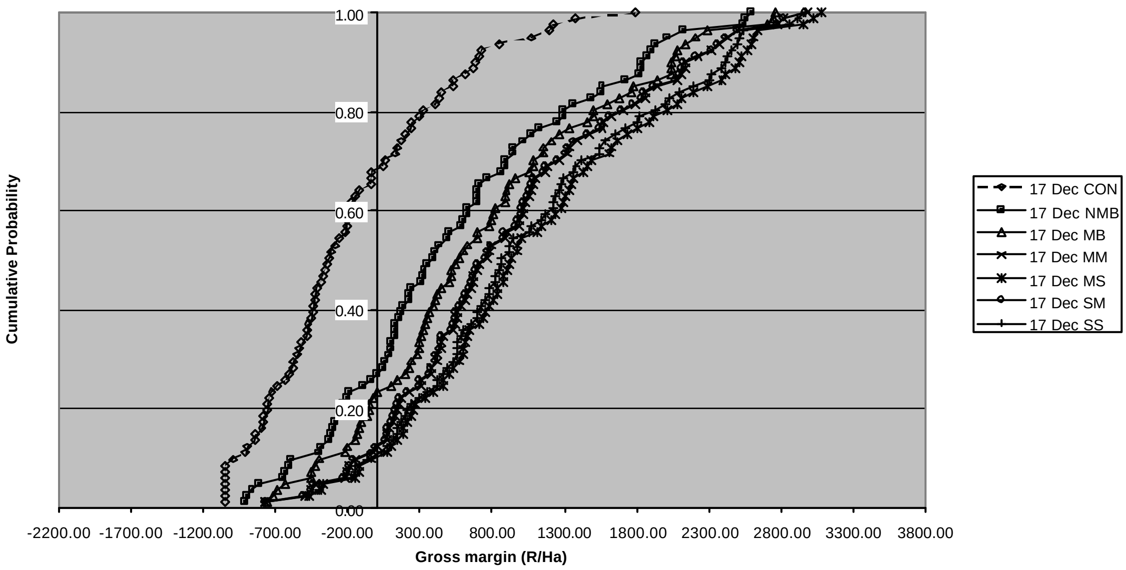


Figure 2, shows the same results as in fig.1 but for sunflower. The same comparison is made as above. BB has the lowest GM than all the IRWH techniques as it lies to the left of all the IRWH techniques functions whereas MS is again the most productive as it lies to the right of all the other IRWH techniques' functions. By implication, MS is stochastically dominant, in the first order, to all other water harvesting techniques and the CON technique. Secondly, IRWH techniques show low levels of risk, as shown by the case of BB as was earlier discussed. MB that lies to the immediate right of the BB function, shows that there is a 23 % chance (P=0.23) of getting a gross margin of zero or less as opposed to 27 % in the case of BB whereas for CON the risk is almost 68 %. The risk further reduces considerably as we move from BB to MS.

Figure 3: Cumulative probability distribution functions based on gross margins(R/Ha) for dry beans over a period of 81 years (1923-2003) for the study area

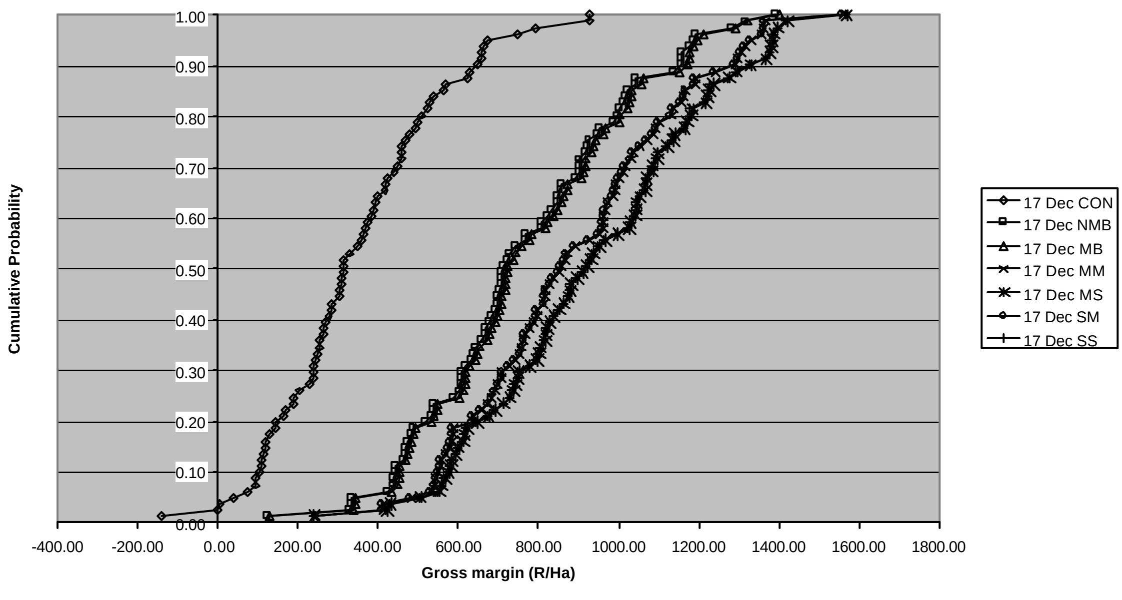


Figure 3 presents CPFs for the production techniques in the production of dry beans. The same trends as observed earlier are also present here. However, CON production shows a lower risk than was the case with sunflower and maize, which might be due to higher price of beans. There is only a 4 % chance of getting a negative gross margin as opposed to the higher risk level associated with the production of maize and sunflower. Secondly, BB dominates MB but below 26 %, the functions are crossing each other and needs a higher order stochastic dominance analysis to decide which one is best. By second degree stochastic dominance BB dominates MB. Another observation peculiar to Figure 3 is that, all the water harvesting techniques do not have any parts of them in the negative gross margin region, implying that there is no chance of yielding a negative gross margin.

6. Conclusions

Water harvesting techniques are a viable new technology that can create new agribusiness opportunities for small-scale farmers in Thaba Nchu.

The profit analysis has shown that the use of IRWH techniques will increase profits as shown by the higher gross margins from production. The risk analysis also showed that the techniques do not only increase profits but they also reduce the risk of negative profits. This implies that IRWH techniques will be good to use in the study area as they provide farmers with opportunities for profitable agricultural production and a less risky environment to operate. Introduction of the techniques will make it beneficial for more farmers to get involved in crop production which will improve food security and also enhance sustainable livelihoods in the study area as well as creating profitable agribusiness opportunities.

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