

Revised Research Article

Decision Support System for Runoff Water Harvesting and Irrigation

Darwin Dodoma Singa¹, Siza Donald Tumbo¹, Mahoo, Henry Fatael¹, Rwehumbiza, Filbert¹ and Lowole, Maxi²

1. Sokoine University of Agriculture, BP: 3003, Morogoro, Tanzania.

Email: dodoma1mwasinga@yahoo.com, dodomamwasinga@live.com

2. Lilongwe University of Agriculture and Natural Resources, Box 219, Lilongwe, Malawi

Abstract

Recurring droughts and dry spells severely disrupt food production and financial attainability in several areas of Sub-Saharan Africa (SSA). The problem is exacerbated by poor or lack of planning for storing rainwater and sizing of irrigation fields in the face of rainfall from existing catchment areas. Versatile agro-hydrological Decision Support Systems (DSSs) are, hence, needed by farmers for effective synchronization of runoff affecting rainfall and catchment factors, rainwater reservoir capacity and irrigation field area. The study, therefore, focused on designing and validating DSS to assist in screening best-bet options for crop field area or reservoir sizes using a case study of common beans (*Phaseolus vulgaris*, L.) and Ukwé Area in Malawi. To design and validate the DSS water reservoir and irrigation components were added to an Agro-hydrological Nedbor Afstromnings Model (NAM). Simulation of parameter optimized results revealed efficiency of the validated DSS to simulate real situation by reliably relating runoff rainwater harvesting, its seasonal open surface storage and irrigable crop land area. Simulated crop water productivity of 0.7 g/L and potential crop command field area of 1.5 ha were achieved. The simulated synchronization values were in agreement with calculated values. The DSS is recommendable to potential users.

Key words: decision, systems, designing, validation, efficiency and simulation

1. Introduction

Recurring and cumulative damage from drought has reduced the yield of crops in many regions (Kamthonkiat, 2008). The negative impacts of droughts and dry spells on crop production in sub-Saharan Africa (SSA) strongly call for supplementary or sole irrigation which needs proper sizing of

29 water reservoir with respect to cropped area or vice-versa. Computerized decision support systems
30 allow users to combine technical knowledge of models that combine crop growth, environmental
31 diversity and economic considerations to make proper implementation of decisions for
32 synchronization of water reservoirs and field sizes (Oteng-Darko *et al.*, 2013).

33

34 Yalewa *et al.* (2014) in South Africa reported that ecosystem services assessment requires an
35 integrated approach, as it is influenced by elements such as climate, hydrology and socio-economics,
36 which in turn influence one another. In Germany, determination of people's willingness to pay, for an
37 improvement of environmental quality and effects of the hydro-morphological measures within the
38 different water bodies, was followed by an economic value assessment for decision making for water
39 framework directive (Hirschfeld *et al.*, 2005). Despite the existence of agro-hydrological DSSs, SSA
40 countries, such as Malawi, have not embraced their use in catchment analysis due to lack of reliable
41 hydrological parameter framework and poor understanding of their application in water storage and
42 irrigation (Njoloma, 2010). The current study intended to address this gap.

43

44 Literature search has revealed a number of models, on which to design and validate
45 a DSS instead of developing a completely new one. However, most of them were
46 found prohibitive for establishing appropriate variable combinations of catchment
47 area, hydrological parameters and crop water productivity. For example,
48 AQUACROP effectively simulates soil and in-situ water variables but does not have the
49 water harvesting-for-irrigation component, hence has limited utility in drought prone SSA
50 countries, such as Malawi. Versatile DSSs, like the one emanating from Predicting Arable
51 Resource Capture in Hostile Environments During the Harvesting of Incident Rainfall in the
52 Semi-arid Tropics (PARCHED-THIRST) model, represent important hydrological processes
53 using physical parameters that are readily available, or easily measured, and used in water harvesting
54 and irrigation (RIU, 2007; Tumbo *et al.*, 2006). However, the model does not yet have long term

55 water storage and legume irrigation components. This was the other gap the study aimed at
56 addressing.

57 Some specific problem domain DSS's have not been comprehensive in hydrological, agricultural and
58 socio-economic sectors (Larbi, 2011). A software system such as the DSS for Agro-technology
59 Transfer (DSSAT) integrates the effects of soil, crop phenotype, weather and management options
60 allowing users to ask "what if" questions and simulate results (Wani *et al.*, 2011). It uses models,
61 such as Vegetation/Ecosystem Modeling and Analysis Program (VEMAP), Crop Environment
62 Resource Synthesis model (CERES), Crop Growth Simulation Model (CROPGRO) and input based
63 crop growth and development simulation model (CROPSIM) series, which do not simulate long
64 term storage of rainwater and soil moisture on crops.

65

66 NAM is a model that is simple and reliable in operation in addition to being versatile and
67 adaptable to sub-Saharan African geo-climatic and crop conditions. The study, therefore,
68 extended NAM model sub-routines, using simple and few data of precipitation, potential
69 evapotranspiration and temperature to simulate runoff to encompass DSS parameters. The
70 DSS development utilized dry season beans, as a study crop, focused on design and
71 validation of a DSS to provide 'what if' solutions emanating from relationships of volume of
72 stored water, irrigation, crop area and socio-economic aspects for strategic and tactical
73 decision making.

74

75 **2. Materials and Methods**

76 **2.1. Study location**

77 The study site, Ukwe, is located in Lilongwe North-West in Malawi. The area is about 1150
78 m above sea level, 13° 46' S and 33 ° 37' E to 13° 55' S and 33° 38' E, extending 13° 46' S
79 and 33 ° 31' E to 13 ° 50' S and 33 ° 32' E, occupying flat *dambo* margins. Temperatures

80 range from 18 to 24°C rising to 29°C just before the start of rains (October to November).
81 The area is drought-prone and farmers have formed a club irrigating common dwarf bean
82 (Kalima variety).
83 Irrigation water was sourced from a small Kalembe dam with catchment area is 16 ha.
84 Weekly irrigation water depth of 50mm, following pre-planting water application of 100 mm
85 was practiced. All agronomic and pathological practices to avoid allelopathy, and biocides for
86 the crop's potential growth and protection recommended by the Ministry of Agriculture,
87 Irrigation and Water Development (MAFS, 2012) were followed. Bi-weekly crop sampling
88 was carried-out for biomass yield with respect to irrigation regimes. The reservoir water was
89 also consumed by 102 heads of cattle and 143 goats. All domestic water was supplied by
90 shallow wells hence reservoir water is not used for domestic chores.

91

92 **2.2. Runoff-Reservoir analysis and Reservoir water, crop water requirement**

93 The reservoir inflows (daily discharges from the catchment area) were measured using a
94 calibrated gauge installed in the reservoir (MIWD, 2011). The volume of water in the
95 reservoir was equated to the seasonal field crop water use. This was related to actual and
96 potential water use yields. Reservoir water balance was based on losses due to seepage,
97 evaporation and livestock consumption. The reservoir water volume balance (after losses
98 through evaporation and seepage, and abstraction by livestock, up to crop harvest week)
99 divided by total seasonal crop water requirement over a hectare provided the total area (ha)
100 the reservoir water could irrigate. The foregoing relationship in turn established optimum
101 sizing of either area or reservoir for maximizing crop productivity based on the runoff
102 generating catchment attributes and climatic conditions. Crop yield and crop-water
103 productivity was established.

104

2.3 Socio-economic analysis of bean irrigation at Ukwe

Economic data measured included labour use, production costs, amount of water applied to each treatment and grain yields. Comparative gross margin analysis and break-even analysis were conducted on rain-fed and reservoir based irrigated bean crops. The gross margin analysis was conducted to indicate profit margin for a farming family, while break-even analysis was conducted to demonstrate a minimum yield a farming family needed to achieve in order to recover money spent on the bean production. Break-even price is described as the minimum output price beyond which the farmer is likely to make profit (Kadyampakeni *et al.*, 2010).

Literature shows a number of approaches to measure willingness-to-pay with differential conceptual foundations and methodological implications (Breidert, et al, 2006). The choice of the survey method used in the study to highlight willingness-to-pay , as a supplementary analysis, was based on its simplicity and literacy level of the respondents.

2.4 Calibration of the Decision Support System

Rainfall data from Lumbadzi, Kandiya and Bunda, 8 km North-east, 12 km East and 30 km South-west of Ukwe respectively, were used to calibrate the MS excel based DSS output for Ukwe site. The model calibration was based on parameter and time constants with respect to climatic values to predict catchment runoff for a given rain storm on daily basis. The reservoir water levels were recorded on weekly time step basis in line with the irrigation water abstraction. A local sensitivity of change in reservoir capacity was obtained from cumulative irrigation withdrawal multiplied by the area irrigated. System behaviour and criteria for selecting optimum reservoir capacity and cumulative irrigation withdrawal as the dry season progressed was established.

Decision support system framework

The Design of the decision support system followed the framework depicted in Figure 1.

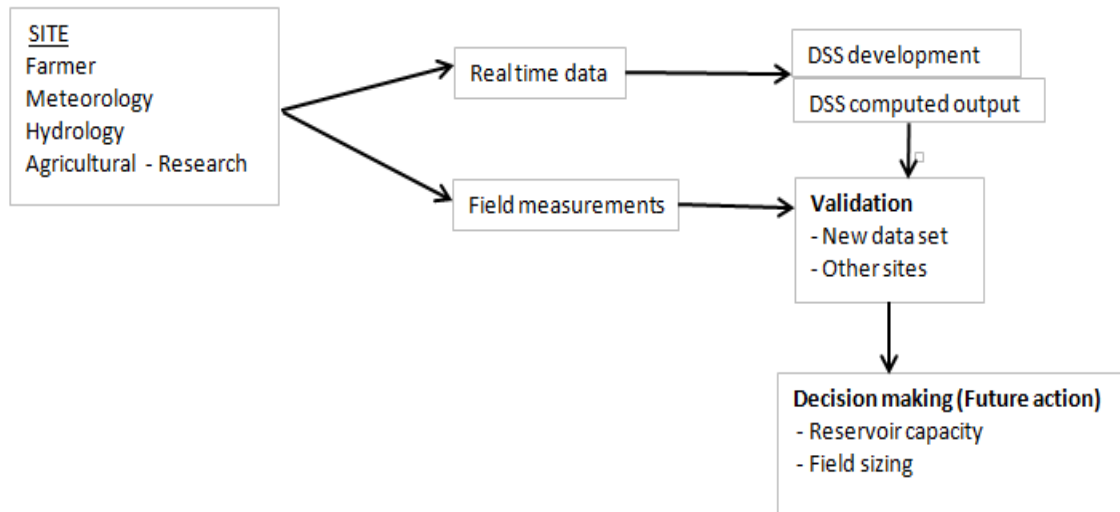


Figure 1: Study framework for the decision support system design

2.6 Input Data to develop a decision support system

The formulated NAM based DSS is a system requiring limited data input. Three input data files, namely meteorological station data file (potential evapotranspiration, temperature and precipitation), Hydrological Department data file (reservoir evaporation and seepage) and agricultural extensionist/farmer data file (head of cattle, goats/sheep, number of persons using the water, irrigation water depth,) are needed for the system to be operational. Collection of data is simple because the meteorological and hydrological data stations in SSA are spread in a number of the agro-ecological zones where weather predictions are made on daily basis. The DSS operation is based on Excel software operation.

In Malawi, the Hydrology Section in the Water Division of the Water Resources Department (Ministry of Irrigation and Water Development), located in the same agro-ecological zone of Ukwe area, is a strong data quality control institution with package of a purpose-built, Windows-based database and analysis system for processing the hydro-meteorological data (HYDATA software), a powerful tool for hydrological data storage, analysis and routine processing (Njoloma, 2010). Rainfall data collection, coordination and storage, in Malawi, is the responsibility of Meteorological and Climate Change Department (Ministry of Transport and Communication) which also trains personnel

149 manning gauging stations on daily basis. For this study, data for DSS validation were sourced from
 150 four stations, Lumbadzi, Ukwe, Kandiya and Bunda in the drought prone plateau region of Central
 151 Malawi, within the agro-ecological zone of the study area (Figure 2).



152

153 **Figure 2: Lower Central Malawi agro- ecological zone weather stations**

154

(Source: Malawi Meteorological Services, 2006)

2.7 Rainfall data screening and operation of the DSS

Rainfall is a vital component of the runoff water harvesting, storage and irrigation. Therefore, initially, the design of the DSS followed test for data consistency and homogeneity, i.e. if data be used for DSS design and validation with confidence. The accumulated mean rainfall data from Ukwé, as it contributed to runoff, was tested against accumulated means from Bunda, Kandiya and Lumbadzi using Double Mass curve method (Ali, 2011).

2.8 Decision Support System Development Procedure

Development of the DSS followed the trend of operation of the system. Initially the system operation requires three main input data sets. Firstly, it requires catchment parameters and time constants, precipitation and potential evaporation so that it can simulate land water storages, and flows which are routed to the reservoir as output. Secondly, it requires data of evaporation and seepage, livestock number (and domestic water use, if any) before it displays reservoir water balance for irrigation. Thirdly, it needs crop water use entry for it to display the required land area to be prepared. The Microsoft (MS) Excel version 1997-2003 NAM based procedure followed the structure depicted in Figure 3.

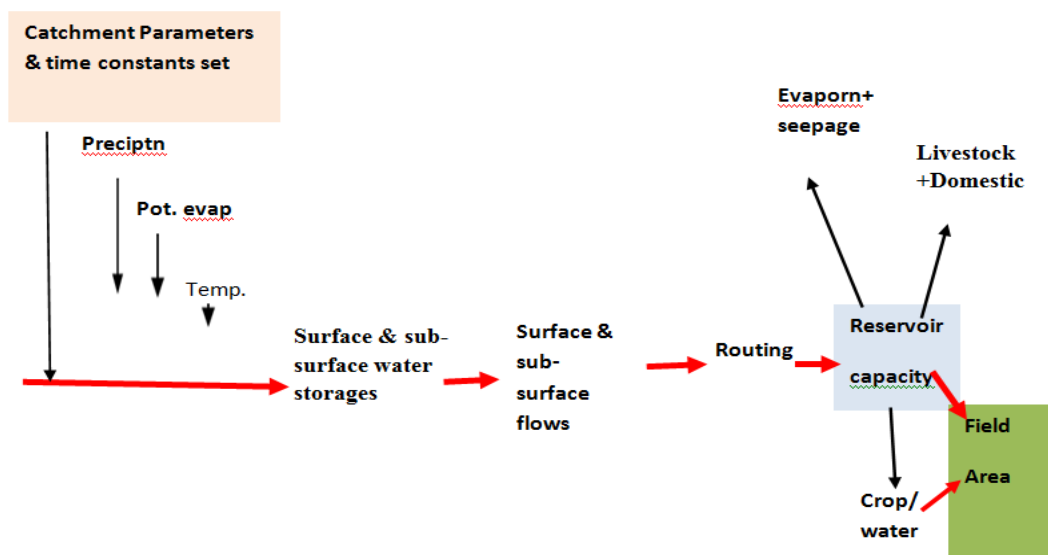


Figure 2: DSS flowchart as per excel based NAM spreadsheet programmed commands

2.9 Catchment characteristic factors

Impacts of the catchment characteristics on runoff and reservoir capacity, as simulated by the modified NAM DSS excel spreadsheet, are quantified by parameterization. The optimized model catchment parameters and routing constants were then used in the design and validation of the DSS (Tables 1 and 2).

Table 1: Model Parameter constants as commands in the spreadsheet*

Parameter	Name	Constants
Lower zone storage capacity: maximum water storage in the root zone	Lmax	> 0
Upper zone storage capacity: maximum water content in the surface storage.	Umax	> 0 First estimate Umax=0.1Lmax.
Snow melt coefficient	Cmelt	0 for Ukwe site
Overland flow runoff coefficient: extent to which excess rainfall runs off as overland flow and the quantity that infiltrates.	CQOF	0 – 1. Since Ukwe catchment is small, small values with low, permeable soils are as expected.
Interflow runoff coefficient: proportion of the surface storage that runs off through horizontal leakage.	CQIF	0 – 1. For catchment with a flat topography the value is very close to zero.
Threshold value interflow:	CLIF	0 – 1
Threshold value overland flow	CLOF	0 – 1
Time Constants for Routing		
Overland and interflow: both flows together are routed through a linear reservoir	CK1	> 0
Stream flow: flow is routed through a linear reservoir.	CK2	> 0
Upper groundwater flow	CKBFU	> 0
Lower groundwater flow	CKBFL	> 0

*Original 'parameter categorization' and 'name abbreviation' from Njoloma, 2010

Table 2: Ukwe DSS adjusted catchment parameters and time constants

Fixed catchment parameters		Time constants	
Lmax	115	CK1	0.5
Umax	10	CK2	0.4
Cmelt	0	CKBFU	0.4
CQOF	0.3	CKBFL	90
CQIF	0.025		
CBFL	0.2		
CLIF	0		
CLOF	0.6		
CLG	0.2		

2.10 Decision Support System Validation

Factors of water routing (modified function of total flows), storage and crop water use and productivity have been incorporated to the NAM based operation using an excel spreadsheet version 2007. Table 3 shows the spreadsheet data input, merged computer simulation (simulatn) columns, cumulative (cummul) dam inflows and dam water balance (dwb). At this point the DSS operator inputs data of pot evaporation (Pot evap), seepage and abstractions by livestock and persons.

Table 3: Decision support system operational design spreadsheet

Date	Computer			Water losses		Water withdrawals			Computer	Crop		Potential
	Simulation	Cummul	DWB	Pot	Seepage	Goat	Cattle	Persons	simulatn	available	Appld	irrigable
	→	dam		evap					→	water	water	Area
		inflows	(m ³)	mm	(m ³)	(m ³)	(m ³)	(m ³)		(m ³)	(cm)	(ha)

3. Results and Discussion

3.1 Rainfall data screening for design of the Decision Support System

The accumulated rainfall means from Ukwe were plotted against accumulated data means of Bunda, Kandiya, and Lumbadzi to test reliability of data. Results of the double mass analysis showed a spurious relationship indicating data inconsistency and non-homogeneity. It would not be reliable, therefore, to use the data for the validation of the DSS unless the source of anomaly is established to be a station other than Uwe.

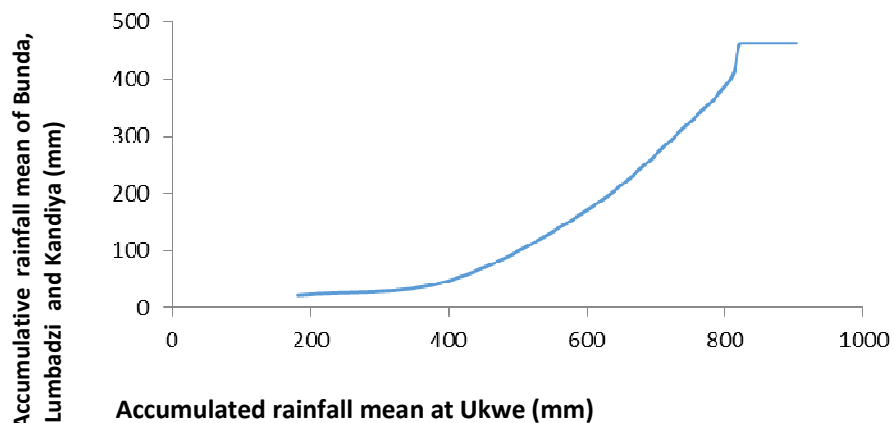


Figure 4: Rainfall double mass analysis of all the stations including Bunda

Although Bunda, Kandiya and Lumbadzi are in the same agro-ecological and agro-hydrological zones, the daily rainfall data from each site was eliminated during each analysis to trace source of the

anomaly. Errors were discovered in the Bunda data. In fact, Bunda site is far removed (50 km) from the rest and is between two mountains, hence it is suspected to have some rainfall variations during some seasons. Generally, weather conditions are reported to gradually change over distances of 50 to 150 km (MARS, 2014). Double mass analysis test was hence run, excluding this Bunda site. The results, as shown in Figure 5, indicate straight line relationship revealing absence of spurious trends. It is worthy pointing-out that Double Mass analysis interpretation is dependent on data line shape rather than use of coefficient of determination (R^2). The analysis, therefore, demonstrated that the rainfall data were valid for runoff and water storage analysis, hence used for the DSS validation.

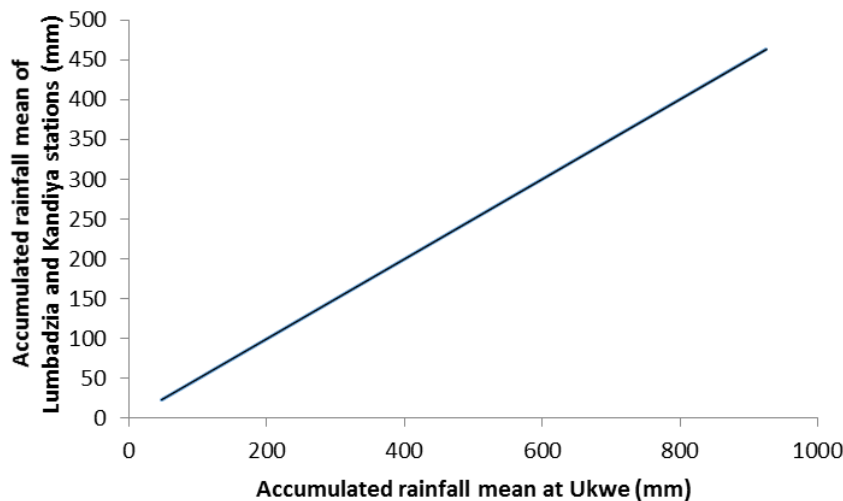


Figure 5: Rainfal double mass analysis of all stations excluding Bunda

3.2 Socio-economic analysis

3.2.1 Gross margin and break-even analyses

Gross margin and break-even analysis was conducted on the grain yield of rain-fed and reservoir water irrigated beans. Variable cost data included production, processing (drying, threshing, treatment) and transportation costs, while fixed costs included contribution towards annual reservoir maintenance (Table 4). Output was in terms of grain yields.

221 The gross margins were higher under irrigation (2.42 times) than under rain-fed bean production
 222 despite additional costs of contribution towards reservoir maintenance and irrigation operations.
 223 Controlled water application during high dry season temperature, with less pest incidences, tends to
 224 make irrigated beans yield higher than rain-fed crop (Kadyampakeni, 2004).

225 **Table 4: Gross margin and break-even analysis for rainfed and irrigated beans**

Details	Unit	Without irrigation			With irrigation		
		Quantity kg	Unit price MK	Total cost MK	Quantity kg	Unit price MK	Total cost MK
Output value	kg	8 012	150	120 000	1 400	165	231 000
FIXED COSTS							
Reservoir contribution	Annual fee	-	-	-	-	-	5 000
Irrigation	Mandays	-	-	-	346	157	54 352
Sub total							59 352
VARIABLE COSTS							
INPUTS							
Seed	kgs	75	250	18 750	75	250	18 750
Insecticides	litres	10	1 500	15 000	10	1 500	15 000
Fungicide	kgs	25	1 000	25 000	25	1 000	25 000
Sub-total (inputs)				58 750			58 750
LABOUR							
Land preparation	Mandays	42	200	8 400	42	200	8 400
Planting	Mandays	15	200	3 000	15	200	3 000
Supply	Mandays	3	200	600	3	200	6 000
Weeding/banking	Mandays	23	200	4 600	23	200	4 600
Harvesting/drying/threshing	Mandays	36	200	7 200	40	200	8 000
Drying/packing/loading	Mandays	15	200	3 000	20	200	4 000
Subtotal for labour	Mandays			26 800			28 600
OTHER COSTS							
Sacks	50 kg bag	12	80	960	30	80	2 400
Transport	bags	12	100	1 200	30	120	3 600
Sub total				2 160			6 000
Total Cost				87 710			152 702
Gross Margin (A-B)	MK/ha			32 290			78 298
A. Break-even Yield	MK/ha			585			925
B. Break-even Price	MK/ha			110			109

Break-even yield was lower than the achieved yield, showing that the bean producers gained from the enterprise and made a profit. Computation of crop water productivity gave the value of 0.7g/L, lower than values of 1g/L reported from experiments elsewhere (Hashim, *et al.*, 2012). The study has shown the benefits of irrigation in comparison to rain-fed farming in the challenging face of frequent droughts and dry spells.

3.2.2. Willingness to invest in irrigation

Farmers were interviewed to know their willingness to pay for runoff water harvesting and irrigation (Table 5). The cost calculated by the dam committee, which an irrigation household was paying for water preservation, is MK5 000 (US\$16.67).

Table 5: Maximum willingness to pay for reservoir construction, maintenance and irrigation

Maximum willingness to pay		Percent
MK	US\$	
< 5 000	<16.67	48.20
5 000 – 10 000	16.67 – 33.34	25.30
10 000 – 15 000	33.34 – 50.01	18.10
>15 000	>50.01	8.40
TOTAL		100.00

Forty-eight percent of farmers would like to pay less than the equivalent US\$16.67. With the need to reforest the catchment area and dam peripheral, only less than 26% of the total number of households would be willing to pay. The rest of the farmers (74 %) would rather do the work themselves as self-help operations. The expectation was that somebody else, either the non-governmental organization or the government, should assist them in paying for such operations. The unwillingness of the small-holder farmers to invest in irrigation infrastructure was similarly reported by Kadyampakeni *et al.*, (2010).

3.3 Decision Support System Spreadsheet Simulation

Operational spreadsheet workbook inputs, with hidden computer simulation command columns (computer simuln) are shown in Table 6. The results of validation based on 2011-2012 data (with hidden command rows and columns for December 2, 2011 to December 31, 2012) displaying Dam Water Balance (DWB) and potential irrigable area are highlighted.

Table 6: Operational spreadsheet workbook simulation highlight for computer simulated and available reservoir water (m³) and potential field area

Date	Factors	Comp			Water losses		Water withdrawals			Computer	Crop	Applied	Potel
Plantg Dec	Climate Land	Simuln	Cumml dam inflows (m ³ /dy)	DWB (m ³)	Pot evap mm	Spq (m ³)	Goat (m ³)	Cattle (m ³)	Human (m ³)	Simuln	Availab Water (m ³)	Water (cm)	Irrigh Area (ha)
Time step (day)													
End Session	Results highlight												ha 16.9
Dec. 31	Temp & Pot evap		10796	10087	1.69	5.7	27.5	122	0		9931	7990	

In addition to simulation of seasonal reservoir water balance and irrigation command (irrigable) area after input of data for water losses and crop water uses, using the spreadsheet commands, the DSS is able to simulate expected yield value and crop water productivity (prdcty) as shown in Table 7.

Table 7: NAM addendum spreadsheet based water loss, irrigation and water balance

Crop Growth (wks)	Measured dam vol. m ³	Evapor m ³	Seepage m ³	Field use m ³ /ha	Water Removal m ³ /ha	Dam Balance (m ³)	Simulate Irrigable crop Area (ha)	Water Yield (kg/ha)	Bean Prdcty g/L
Pre-planting	9978	6	11	500	517				
1 to 2	9015	9	16	1500	1525				
5 to 9	4646	10	19	2000	2029				
6 to 10	2541	8	15	2000	2023				
TOTAL	0	33	61.0	6000	6094	3884	17	1400.0	0.7

The DSS simulated synchronization of reservoir water and land area (1.5 ha) is equivalent to the calculated area (1.6 ha) based on the research recommended bean crop irrigation depth of 5 cm per week, if static application rate is followed. This validates the DSS for utilization to establish reservoir capacity and/or corresponding crop land area.

4. Conclusions and Recommendations

4.1 Conclusions

Socio-economic analysis has indicated clear benefits for the farmers producing the common beans (*Phaseolus vulgaris*, L.) using stored runoff water. Availability of a decision support system to help in determination of required crop field area in relation to the reservoir water capacity or vice-versa is vital. The structure and spreadsheet entries of the DSS have been designed and validated. Two dry season crop production cycles, at crop water productivity of 0.7 g/L, as the case at Ukwé Area, would require potential crop command field area of 1.5 ha. The DSS has comparative advantage to others, developed for rainwater harvesting for irrigation, because apart from using simple data entry it is versatile in simulating runoff, long term surface water storage capacity and synchronized crop land area farmers need to prepare to meet the recommended crop water requirement.

At national level, the Early Warning Section of the Ministry of Agriculture and Food Security anticipates using the DSS, given climate forecasts, to predict crop yield and mitigate drought and dry spell impacts. The DSS provides, stakeholders such as farmers and agricultural research and extension workers, a simplified procedure for determination of reservoir water capacities, given climatic forecasts, catchment characteristics and crop water requirement, in order to plan for dry season crop field sizing. At agricultural academic institutions in SSA the DSS can be included in curricula modules and research projects.

4.2 Recommendations

It is recommended that it be further validated on different crops, apart from common beans, and other agro-ecological zones, apart from Lilongwe Plateau Area, for wide-scale utilization. Furthermore, in addition to spreadsheet data entry operational structure, a computer interface be developed. The user can perform progressive interactive data entry starting with fixed catchment parameters and time constants as the DSS data base memory to evoke prominent catchments used for water harvesting. Then a window should display a request for predicted precipitation entry, then potential evaporation value followed by temperature to achieve seasonal reservoir volume display. The user will be asked to enter seepage, then evaporation values to get a new reservoir balance and get crop water application interface. Once a figure is entered the computer interface will display the field area to be prepared. The procedure would be an option to the presented excels spread sheet data entry used in this study.

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366 **6. List of acronyms and abbreviations**

367 AQUACROP Crop water productivity model which simulates yield response to water

368 APSIM Agricultural Production Simulator

369	CERES	Crop Environment Resource Synthesis
370	Commul	Cumulating
371	Crop availab	Crop available water
372	CROPGRO	Crop growth model
373	CROPSIM	Package with functions for dynamic & mechanistic simulation of crop
374		growth and development in response to inputs
375	CWP	Crop water productivity
376	CWR	Crop water requirement
377	D	Maximum water depth
378	DSS	Decision Support System
379	DSSAT	Decision Support System for Agro-technology Transfer
380	DWB	Dam Water Balance
381	DGPS	Differential Global Position System
382	EV	Evaporated water volume (m ³)
383	Evapn	Evaporation
384	E _{reservoir}	Reservoir evaporation
385	GEV	General extreme value
386	ha	hectare
387	HYDATA	Purpose-built, Windows-based database and analysis system for processing
388		hydrometeorological data
389	H & S	Harvested and stored respectively
390	ICRISAT	International Centre for Research in semi-Arid Tropics
391	IDRC	International Development Research Centre
392	IFAD	International Food and Agricultural Development
393	ITDG	Intermediate Technology Development Group

394	IWMI	International Water Management Institute
395	m ²	Square metres
396	MAFS	Ministry of Agriculture and Food Security
397	MIWD	Ministry of Irrigation and Water Development
398	NAM	<i>Nedbor Afstromnings</i> Model
399	PARCHED -THIRST Predicting Arable Resource Capture in Hostile Environments	
400	During the Harvesting of Incident Rainfall in the Semi-arid	
401	Tropics	
402	Pot evap	Potential evaporation
403	Pot irrigb	Potential irrigable area
404	Res. Balance	Reservoir balance
405	RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
406	SADC	Southern African Development Community
407	Spg	Seepage
408	SSA	Sub-Saharan Africa
409	Temp	Temperature
410	US\$	United States Dollar
411	VEMAP	Vegetation/Ecosystem Modeling and Analysis Program