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Crop Diversity Measurement at Dufuya Gardens and Insukamini Irrigation Scheme in Lower Gweru Communal Lands

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Abstract: Dufuya wetland gardens and Insukamini irrigation scheme in Lower Gweru communal areas of Gweru district are two examples of how rural communities can be self-reliant if they are capacitated. This study sought to compare crop diversity between these two vegetable producing schemes. The location of the two areas and the selected plots were determined using the GPS (global positioning system) hand receiver. Maps of the quadrants were produced in a GIS (geographic information system) on a computer. Simpson's index D = sum (Pi^2) was used to measure crop diversity while the Shannon-Weiner index (H) was used to measure crop evenness. Results show that although both schemes are viable, Dufuya Gardens have higher crop diversity than Insukamini irrigation scheme. The study recommends that AGRITEX officers at Insukamini must advise farmers to diversify their crops in order for their produce to be more competitive on the market and also to cushion farmers against the effects of natural hazards. Given the success of the two schemes, the government must seriously consider sustainable utilization of the many small-scale dams and wetlands lying idle across the country for crop production in order to empower poor rural communities as well as alleviate poverty.

Key words: Crop diversity, evenness, Simpson's index, Shannon-Weiner index.

1. Introduction

Zimbabwe's climatic conditions are largely subtropical with one rainy season between November and March. According to Chitembure [1], only 37% of the country receives rainfall considered adequate for agricultural activities. The government of Zimbabwe has however recognized the importance and role of irrigation development as a supplement to water scarcity especially in drought situations. It is estimated that 12,000 ha of land is under irrigation of which 11% is under small-holders and out-grower schemes [2, 3]. The promotion of irrigation in the country has played an important role in ensuring food security thereby improving the standard of living for the majority population both in urban and rural areas.

Insukamini dam which is found in Lower Gweru communal area of the Midlands province is located along Ngamo River in the Munyati basin. It was constructed in 1986 by a NGO (non-governmental organization) called DANIDA through facilitation from the government. The presence of the dam in the area resulted in the establishment of Insukamini irrigation scheme in 1988. The irrigation scheme has since then become a major supplier of vegetables produce to nearby Gweru, the provincial capital city.

On the other hand, wetlands (or dambos) have also played a very important role in sustaining rural livelihoods since they provide fertile soils to support intensive agriculture and pastures for livestock [4, 5]. According to Hirji et al. [6], a wetland is an area of land whose soil is saturated with moisture either permanently or seasonally. They include swamps,

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marshes, dambos and vleis whose depth does not exceed 6 meters [7]. In a wetland, water is the primary factor controlling the environment and the associated habitats. Wetlands occur where the water table is at or near the surface of the land, or where the land is covered by shallow water. Because of their biological richness, wetlands have been manipulated for agricultural production. For example, in Albania 90% of the land was drained to increase food output and some of the marshes were converted into irrigated agriculture [8].

In Zimbabwe, wetland utilization was once restricted by the 1976 Water Act and the Natural Resources Act which restricted them to grazing only. This changed with the enactment of the EMA (Environmental Management Act) chapter 20:27 section 113 which made a provision for the sustainable use and protection of wetlands [9]. Zimbabwe has since then been involved in a number of wetland protection and utilization projects facilitated by the Small Grants Program. These include the Biodiversity Conservation Project of Gutu, Madyamhuru Wetland Protection in Murewa, Sowala-Madigane and Dufuya Integrated Project in Lower Gweru [10]. A common feature in all these projects is that they are aimed at protecting and increasing biodiversity and enhancing sustainable utilization.

While it is commendable that small dams and wetlands in some dry rural areas are being exploited for the benefit of surrounding poor communities, it is important that sustainability be assured both on the ecological and socio-economic front. That is, while it is good to protect wetlands and small dams from animal paddling as well as from possible invasive species among other pests on the one hand, it is equally important that diversity be ensured also on the crop fields. In other words, farmers should plant a variety of crops to ensure diverse options in marketing and also to reduce competition among them on the market. This is because diversity ensures profitability. It also improves nutrition within the community and thus lowers chances of opportunistic illnesses. Crop diversity is also a cushion in times of poor performance by other crops through various vicissitudes of the local weather and climate like frost, strong winds, pests, diseases and even fire outbreaks.

It is against this backdrop that the researcher sought to measure species diversity for both Dufuya wetland gardens as well as Insukamini irrigation scheme to establish which between the two is more diverse and therefore more resilient and hence more reliable for the farmers.

According to Rosenzweig [11] species diversity is the variety of different types of organisms or species present in an ecosystem. It is determined by diversity indices. A diversity index is a mathematical measure of species diversity in a community. Diversity indices provide more information about community (e.g. vegetables) composition than species richness which is simply the total number of different organisms (or different vegetable stems) present [12-14]. For the purposes of this study, the researcher used Simpson's index [15] and the Shannon-Weiner index [16] to determine both species diversity and species evenness in both Dufuya and Insukamini agro-ecosystems.

2. Description of the Study Areas

Both Dufuya and Insukamini areas are characterized by large stretches of plain land which gently undulates and is generally interrupted by deep valleys and small streams. Vegetation type is Parkland Savanna or Open Savanna which consists mainly of indigenous deciduous trees such as *musasa* (*Brachystegia speciformis*), *mupfuti* (*Brachystegia boehmii*), *mopane* (*Colophospermum mopane*) and *muhacha* (*Parinari curatellifolia*). More concentration of trees is found along rivers. For Insukamini, soils are generally sandy loam, low in organic matter because of sparse vegetation while Dufuya has wet gleysols and hydrophitic vegetation. Soils are derived from granite and vary in colour and texture. In times of more than normal rainfall, soils at Insukamini usually become heavily leached. Being in the same district, both areas receive moderate rainfall of between 600-800 mm per year. Mid-season dry spells are common for both areas in summer. Mean annual temperature is 20-30 °C.

2.1 Dufuya Integrated Project

Dufuya integrated project is located about 50 km south-west of the Midlands city of Gweru in Lower Gweru communal area of Gweru district. With the assistance of Heifer International Zimbabwe, the project established horticultural gardens, constructional livestock watering troughs, wetland rehabilitation, agro forestry units, livestock fodder banks and fish pond [10]. The project is a community initiative with the facilitation of Heifer International Zimbabwe's Small Grants Program which provided technical support. The community has set up leadership committees to coordinate activities. The aim of the project is to build capacity of local communities in restoring, protecting and sustainably utilizing the wetland which was under threat of extinction due to uncontrolled utilization and livestock paddling [10].

The project puts emphasis on the sustainable livelihoods of the Dufuya community and this has been realized mainly through the production of horticultural products mainly vegetables. Important features of Dufuya integrated project are Dufuya Gardens which get water from a perennial spring upslope through the gravity method. These gardens support 331 households and 85% of the plot holders are women. 8% of the beneficiaries on the gardens are orphans of the HIV/AIDS pandemic who have found a source of livelihood in the scheme. Dufuya Gardens are fenced and most of it is devoted to vegetable production for most of the year except in summer when some farmers grow the staple maize crop.

2.2 Insukamini Irrigation Scheme

Insukamini irrigation scheme was established by the government in 1988 following the construction of Insukamini dam by DANIDA in 1986. It lies about 17 km south-west of the Midlands capital, Gweru in Lower Gweru communal lands. Like Dufuya, Insukamini lies in Zimbabwe's natural farming region 3 which is drought prone. Among the reasons for the establishment of the scheme was poverty alleviation in the rural community (given the unpredictable nature of rainfall), food security enhancement as well as the empowerment of local farmers. Farmers who benefitted were those with Master Farmer certificates or those with membership to agricultural groups and in possession of basic farming implements. The scheme gets water from Insukamini Dam via a 3 km open concrete canal through the force of gravity. 70% of the members are women.

The scheme is divided into two blocks, A and B. Block A is subdivided into A1, A2 and A3 where A1 is occupied by 41 members each entitled to 0.5 hectares of land. A2 is occupied by 27 members each entitled to 0.2 hectares of land. The scheme is undergoing some expansion where block 3 is an expansion of block A. Block A3 is occupied by 45 members again each with 0.2 hectares of land. The recently expanded block B is subdivided into blocks B1 and B2 where each member is entitled to 0.2 hectares of land. Reasons for the expansion of the scheme include the need to increase food security within the community, to utilize the available land which was lying idle as well as the need to accommodate growing up children of members.

Like Dufuya Gardens, Insukamini is essentially a vegetable project which produces various legumes, leaf crops and fruit crops. The scheme gets assistance from the Grain Marketing Board (subsidized inputs), the European Union (fencing of the blocks and toilet construction), DDF (District Development Fund) (borehole drilling) and an NGO, CARE (links farmers with markets). To boost farmers' knowledge, farmers receive training assistance from Agricultural Extension Officers (AGRITEX).

3. Materials and Methods

3.1 Maps Showing the Study Areas

The two areas under study were classified as quadrants with Dufuya Gardens being assigned to be quadrant 1 whilst Insukamini irrigation scheme became quadrant 2. Each quadrant comprised of 18 plots which were randomly selected using GIS (geographic information systems) techniques to represent the areas under crop production. The exact locations of these 18 plots were identified using the GPS (global positioning system) Garmin Etrex legend hand receiver. The numbers of crop species were obtained by observing and physically counting the stems above the ground. Pen and paper collection sheets were used to capture and record data in the field.

Coordinates of the located plots were collected using the UTM (Universal Transverse Mercator) system. The coordinates were then entered in MS excel spreadsheets and saved as Text (Table Delimited) and then converted to a shape file. This was followed by the addition of attribute data to the theme layer. The attribute data comprised of the names of crop species found on the sampled plots as well as their number of stems above the ground. Maps of the two quadrants shown in Figs. 1 and 2 were produced using a computer with a GIS ArcView 3.2a package.

3.2 Simpson's Index

Simpson's index, which is a measure of diversity which accounts for both species richness and proportion (e.g. percentage) of each species, was used to determine diversity. This index was determined using the formula:

$$D = \text{sum}\,(Pi^2) \qquad (1)$$

where,

D is diversity;

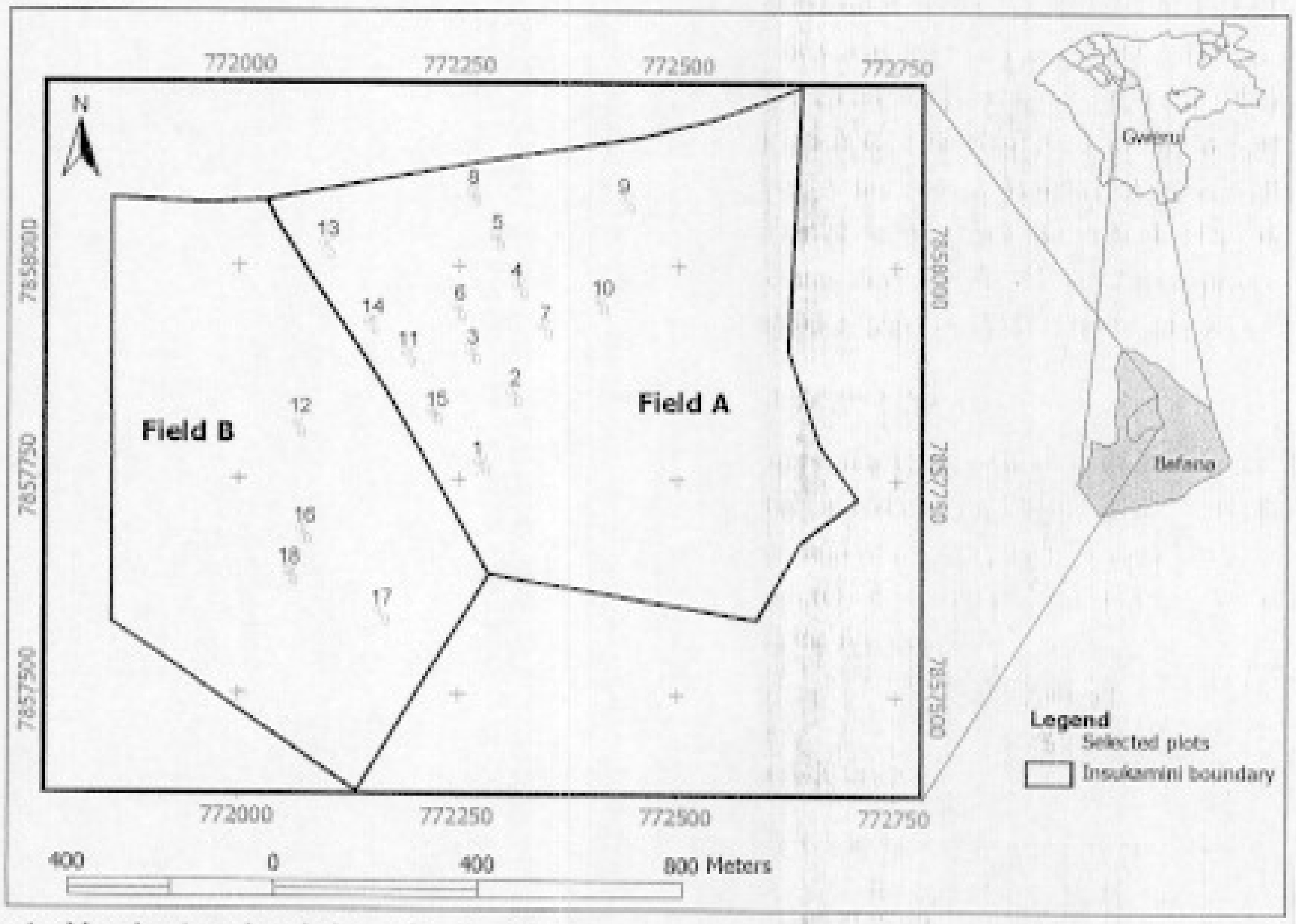

Fig. 1 Map showing selected plots at Insukamini.

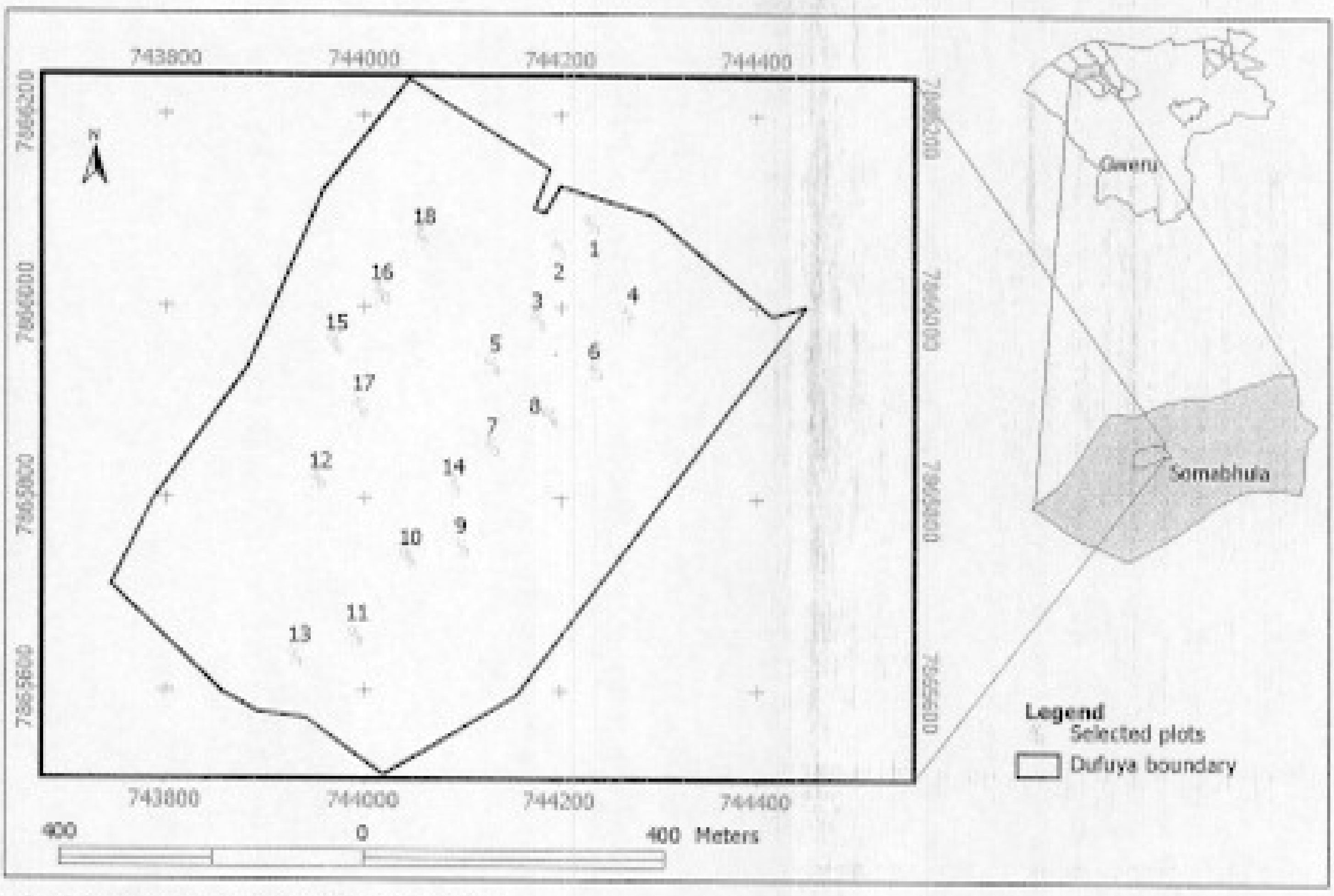

Fig. 2 Map showing selected plots at Dufuya.

Pi is the number of a given species divided by the total number of organisms observed.

The above formula proves the probability that two randomly selected individuals in a community belong to different categories of species. The first step is to calculate *Pi*. A lower probability reflects a higher diversity while a higher probability indicates lower diversity [13].

It was also necessary to measure species evenness between the two sample plots to determine how similar the abundance of different species were. When there are similar proportions of all species then evenness is 1, but when the abundance are very dissimilar (some rare and others common) then the value increases.

3.3 Shannon-Weiner Index

To calculate species evenness, the Shannon-Weiner index (*H*) was determined first. Shannon-Weiner index is a measure of diversity which measures the order (or disorder) observed within a particular system. Similar to Simpson's index, the first step is to calculate *Pi* for each species. The Shannon-Weiner index was determined using the formula:

$$H = \text{sum}\,(Pi \ln [Pi])\ (\text{Natural log}) \quad (2)$$

where,

H is Shannon-Weiner index;

Pi is the number of a given species divided by the total number of organisms observed;

ln is the natural log.

Using species richness (*S*) and the Shannon-Weiner index (*H*) species richness was then computed using the formula:

$$E = H/\ln(S)\ (\text{Natural log}) \quad (3)$$

where,

E is species evenness;

H is the value for Shannon-Weiner index;

ln is natural log;

S is species richness.

4. Results

In Table 1, it is shown that using a simple count of species, quadrant 1 (Dufuya Gardens) has more species (18) than quadrant 2 (Insukamini irrigation scheme) which has only 10. It is generally assumed that an area with high species richness is often more diverse [16]. However, to prove this assumption, Simpson's index was employed to calculate species diversity between Dufuya Gardens and Insukamini irrigation scheme.

As afore stated, Simpson's index: D = sum (Pi^2) tests the probability that two randomly selected individuals from a sample plot belong to the same species. A lower probability reflects a higher diversity while a higher probability indicates lower diversity. In this case the probability that two randomly selected individual species of vegetables (or crops) belong to quadrant 1 (Dufuya Gardens) is 0.13 which is lower than that for quadrant 2 (Insukamini irrigation scheme). This means that Dufuya Gardens is more diverse because the probability that the same species at Insukamini irrigation scheme will be selected is 0.8

Table 1 Diversity results from Simpson's index D = sum(Pi^2).

X	Y	Species	Number of species	Species richness	Pi	Pi^2	D
Quadrant 1 (Dufuya wetland gardens)							
744,461	7,866,352	Beans	7,154	18	0.21	0.0441	0.13
		King onions	6,274		0.19	0.0361	
		Peas	5,262		0.16	0.0256	
		Shallots	3,191		0.10	0.0100	
		Covo	2,596		0.08	0.0064	
		Butternuts	2,145		0.06	0.0036	
		Sweet potatoes	2,143		0.06	0.0036	
		Okra	1,474		0.04	0.0016	
		Tomatoes	1,114		0.03	0.0009	
		Cabbages	740		0.02	0.0004	
		Carrots	641		0.02	0.0004	
		Sugarcane	191		0.006	0.000036	
		Rape	180		0.005	0.000025	
		Bananas	58		0.002	0.000004	
		Guavas	38		0.001	0.000001	
		Mangoes	33		0.001	0.000001	
		Spinach	31		0.009	0.0000008	
		African reed	13		0.003	0.00000009	
						0.13	
Quadrant 2 (Insukamini irrigation scheme)							
772,043	7,859,160	Wheat	37,000,000	10	0.90	0.81	0.81
		Beans	201,606		0.05	0.025	
		Peas	115,860		0.03	0.0009	
		Onions	52,735		0.01	0.0001	
		Rape	7,736		0.002	0.00004	
		Maize	4,816		0.001	0.000001	
		Cabbage	4,441		0.001	0.000001	
		Spinach	2,168		0.0005	0.00000025	
		Tomatoes	1,670		0.0004	0.00000016	
		Garlic	1,600		0.0003	0.00000009	
						0.81	

Table 2 Evenness results from Shannon-Wiener index (1949).

			Quadrant 1 (Dufuya wetland gardens)						
X	Y	Species	No. of species	SR	*Pi*	ln (*Pi*)	*Pi* ln (*Pi*)	*H*	*E*
744,461	7,866,352	Beans	7,154	18	0.21	-1.56064	0.328944	2.188716	0.748
		K.onions	6,274		0.19	-1.6607	0.315533		
		Peas	5,262		0.16	-1.8225	0.29176		
		Shallots	3,191		0.10	-2.3025	0.23025		
		Covo	2,596		0.08	-2.5257	0.202056		
		Butternuts	2,145		0.06	-2.8134	0.168804		
		S.potatoes	2,143		0.06	-2.8134	0.168804		
		Okra	1,474		0.04	-3.21887	0.12875		
		Tomatoes	1,114		0.03	-3.5065	0.105195		
		Cabbages	740		0.02	-3.9120	0.07824		
		Carrots	641		0.02	-3.9120	0.07824		
		Sugarcane	191		0.006	-5.1159	0.03069		
		Rape	180		0.005	-5.2983	0.02649		
		Bananas	58		0.002	-6.2146	0.01242		
		Guavas	38		0.001	-6.9077	0.00690		
		Mangoes	33		0.001	-6.9077	0.00690		
		Spinach	31		0.009	-7.0141	0.00631		
		African reed	13		0.003	-8.1117	0.00243		
							2.188716		
			Quadrant 2 (Insukamini Irrigation Scheme)						
772,043	7,859,160	Wheat	37,000,000	10	0.90	-0.10536	0.094824	0.4314	0.1874
		Beans	201,606		0.05	-2.9957	0.149785		
		Peas	115,860		0.03	-3.50655	0.105195		
		Onions	52,735		0.01	-4.6051	0.046051		
		Rape	7,736		0.002	-6.2146	0.01242		
		Maize	4,816		0.001	-6.9077	0.006907		
		Cabbage	4,441		0.001	-6.9077	0.006907		
		Spinach	2,168		0.0005	-7.6009	0.00380		
		Tomatoes	1,670		0.0004	-7.8240	0.00312		
		Garlic	1,600		0.0003	-8.1117	0.0024		
							0.43140		

meaning lower diversity. To calculate and compare species evenness between the two agro-ecosystems, the Shannon-Weiner index (H) was used.

From the results shown in Table 2, the Shannon-Weiner index (*H*) for Dufuya is 2.188716 and its evenness (*E*) is 0.748 which are both higher than those for Insukamini with *H* of 0.4314 and E of 0.1874. According to the Shannon-Weiner index, when there are similar proportions of all species, then evenness is 1 but when the abundance are very dissimilar, then the value of evenness (*E*) increases [16]. With an evenness of 0.748 which is much closer to 1, Dufuya has a higher evenness than Insukamini which has an evenness value of 0.1874.

5. Conclusion

Insukamini small-scale irrigation and Dufuya wetland gardens are examples of viable schemes which have helped to alleviate poverty in the semi-arid region of Lower Gweru in Gweru district of Zimbabwe. The construction of Insukamini dam is the reason for the establishment and success of Insukamini irrigation scheme while on the other hand the existence of the Sogwala-Dufuya-Madigane wetland is also the premise upon which Dufuya wetland gardens thrive. Beneficiaries of plots in both areas have managed to build some decent homes; they have also managed to send their children to school and have families which are generally healthy. Comparatively however, Dufuya Gardens have higher crop diversity than Insukamini irrigation scheme and this is mainly because of the natural and perennial nature of soil moisture which supports different crops even during the dry season. Any part of the gardens can support crops even with little care from the farmers unlike at Insukamini where crops can only thrive where water has been directed by the farmers from the concrete canals. Farmers at Insukamini also follow an annual production calendar which dictates which crops are to be grown at which time of the year by all farmers. This tends to flood the market with similar products resulting in lower monetary returns to individual farmers. With higher crop diversity, farmers at Dufuya have more options with their produce. Each farmer produces whatever he/she wants and this reduces the monotony of produce on the market resulting in more financial returns for the farmers. Even their families will comparatively be more nourished and in case of a plague or devastating crop infection some crops will prevail. This reduces farmer vulnerability in bad times.

6. Recommendations

On the basis of the findings from this study it is recommended that:

- Given the general success of Dufuya Gardens, more people should be apportioned land on other wetlands especially in other drier parts of the country in order to alleviate poverty in those areas as well. Emphasis, however, needs to be put on the sustainable utilization of these ecosystems as is the case at Dufuya where the water source for the wetland (fountain) is fenced.
- The many idle small-scale dams throughout the country (and even some large-scale ones like Mthabezi in the heart of the very arid region of Matabeleland South) should be availed for utilization by surrounding poor local communities who always suffer the brunt of drought. This can be achieved with the help of NGOs (Non-Governmental Organizations) or government departments like the Ministry of Community Development and Women's Affairs.
- Agricultural Technical and Extension (AGRITEX) officers at Insukamini scheme must advise farmers on the need to diversify their produce in order for their produce to be more competitive on the market. Such diversity will also cushion farmers against the effects of natural hazards like drought, frost and hail among others.

References

[1] R.R. Chitemburе, Irrigation Projects in Zambezi River Basin, Project No. 51, Harare, 1997.

[2] M. Chenje, L. Sola, D. Paleczny, The State of Zimbabwe's Environment, Ministry of Mines, Environment and Tourism, Government of Zimbabwe, Harare, 1998.

[3] S. Young, Irrigation Schemes: A Response to World Hunger, Oxford University Press, London, 2002.

[4] J.R. Whitlow, Research on Dambos in Zimbabwe, Zimbabwe Agricultural Journal 82 (1985) 29-66.

[5] A.A. Ghabo,Wetland Characterization in Kenya, Use by Local Communities and Role in Supporting Biodiversity in Semi-arid Ijara District, Kenya,Terra Nuova East Africa Press, Nairobi, 2007.

[6] R.J. Hirji, P. Maro, C.T. Matiza, Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa, SADC/World Bank, Harare, 2002.

[7] C.T. Matiza, Overview in Wetlands and Ecosystems and Priorities for Conservation in Zimbabwe, IUCN, Gland, Switzerland, 1994.

[8] N. Middleton, The Global Casino: An Introduction to Environmental Issues, 3rd ed., Oxford University Press, Oxford, 2003.

[9] The Environmental Management Act, Government Printers, Harare, 2002.

[10] Small Grants Program, Dufuya Integrated Project, UNDP, Global Environmental Facility Web Site, http://sgp.undp.org/web/projects/6511/dufuya_integrated_wetland_protection_management_sustainable_utilisation_and_biogas_establishment.html (accessed Sept.10, 2011).

[11] M.L. Rosenzweig, Species Diversity in Space and Time,

Cambridge University Press, New York, 1995.

[12] E.P. Odum, G.W. Barrett, Fundamentals of Ecology, Peter Marshall, India, Bangalore, 2005.

[13] M. Begon, J.L. Harper, C.R. Townsend, Ecology: Individuals, Populations and Communities, 3rd ed., Blackwell Science Ltd., Cambridge, MA, 1996.

[14] A.E. Magurran, Ecological Diversity and Its Measurement, Princeton University Press, Princeton, NJ, 1988.

[15] E.H. Simpson, Measuring of biodiversity, Nature [Online], 163 (1949) 688, http://en.wikipedia.org/wiki/Simpson_index (accessed Aug.10, 2011).

[16] C.E. Shannon, W. Weaver, The mathematical theory of communication, in: Measurement of Biodiversity [Online], http://en.wikipedia.org/wiki/Shannon_index (accessed May 2011).