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The Impact of Rainwater Harvesting Ponds on the Ecosystem Productivity in Rwanda

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Abstract

This paper aimed to investigate the influence of rainwater harvesting ponds on ecosystem productivity in Rwanda by referring to Cyeza sector of Muhanga district. Nine parameters of water sampled namely PH, electric conductivity, total dissolved solids, calcium, magnesium, HCO_3, sodium, PO_4 and NO_3 were analyzed to come up with water quality assessment in ponds. Provisioning and regulating services as ecosystem services were discussed based on pond water availability and quality. SPSS, laboratory and Microsoft excel were used to analyze these water parameters and spread the resulting nationally. The results showed that the water sample taken was not desirable for both animal and human drinking (affect health problems) but was also showed that the water was crucial for farming irrigation that leads to plant growth (contain some minerals as Na, Mg, Na that are necessary for plant development). 75.5% of farmers testified that RWH ponds offer them good crop yields, 98.1% of the respondents testified that before adopting RWH technology, the level of crop productivity was totally low, whereas after adopting RWH ponds, the findings showed that the level of crop productivity was increased from moderate to very high level represented by 52.8%, 37.7% and 9.5% consecutively. This implies that crop productivity has been dramatically increased after adopting RWH ponds as shown in the table 7. The results of this study can help policy makers to understand the community requirements and ensure spread of policies that could help farmers to adopt and use efficiently rainwater harvesting ponds that lead them to good cropping yields.

Keywords

Rain Water Harvesting Ponds, Ecosystem, Productivity, Cyeza Sector and Rwanda

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1. Introduction

Globally, most people are engaged in different activities such as agriculture, farmers, etc,… they have engaged in water harvesting. The act of harvesting rainwater, floodwaters and groundwater has been in practice for thousands of years, from the most rudimentary techniques to large, complex methods such as the roman aqueducts. For many cultures, water harvesting (WH) was an effective way to meet their water needs in a time when no other alternatives were available to them. This was mainly due to the fact that alternative sources of drinking water and water for agricultural purposes were not readily available. Historically, many settlements have been situated in arid and semi-arid climates, such as the Middle East, Northern Africa, and Western Asia. These cultures were largely dependent on subsistence farming and there were few other opportunities to generate income. WH became widespread in many of these regions and although various methods were devised almost universally, each emerging culture established their own unique way of collecting or diverting runoff for productive purposes [1].

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Middle East was one of the greatest areas in the world to exercise harvesting water for utilisation in both domestic and agricultural realms. WH assembly found in this three part of the world date back over 9,000 years, to Southern Mesopotamia where simple WH assembly were initiated as early as 4,500 BC [1]. In the Negev Desert region, now present-day Israel, runoff irrigation farming has been in execution since the 10th century BC. This form of WH was used through Roman rule and well into the Byzantine era [1]." In North Yemen, a system dating back to at least 1,000 BC diverted enough floodwater to irrigate 20,000 hectares (50,000 acres) making agricultural products that may have fed as many as 300,000 people" [1].

In Asia, numerous communities have emerged and thrived in harsh arid regions, where their social life has evolved all over dryness and indigenous water harvesting techniques. India is one such country where the requesting of certain social groups has to put in place around water shortage. National annual average rainfall in India reaches to 120 cm, yet the regional variations of this average can be as high as 1000cm per year in the north east and as low as 15 cm per year in the desert regions [2]. In the cool arid region of the Spiti valley situated in the northern province of Himachal Pradesh, intricate systems of channels called Kuls have been devised to harvest melt water from glaciers. This water is then delivered to the local village(s) in the valley where the harvested water is used for irrigation purposes, turning this desert-like valley into one where agriculture is the mainstay.

Northern Africa, has a long history of WH, where the method was often devised to match the terrain of each region. Historically spoken as the granary of the Roman Empire, in Libya, runoff irrigation was often utilised as a way to grow barley, wheat, olive oil, grapes, figs and dates in this arid region of the continent. As well, this form of water harvesting also allowed for sheep, pigs and cattle farming [3]. Many of the other WH methods employed in this region are still used today and include; rainwater storage ponds called "lacs collinaires" in Algeria, the Meskan and Mgouds harvesting systems in Tunisia, the Caag and Gawan systems in Somalia and finally the Zay system in Burkina Faso.

In Tanzania, east Africa, water harvesting has been a mainstay with rural farmers using rainwater harvesting to irrigate their crops for centuries. "People who rely completely on rainwater for their survival have over the centuries developed indigenous methods to harvesting rainwater" [4].

These indigenous methods include the Majaluba, excavated bunded basins used for rice production in the lake zone, Vinyungu, raised broad basins in the Iringa region, and the Ndira, which are water storage structures in the Kilimanjaro region [4].

In Rwanda, the issue of variability of rainfall is critical for lands on hillsides where water cannot be retained. Farms in the eastern part of the country, where rainfall is lowest, are therefore the most vulnerable [5]. Under these conditions, rain-fed agriculture, which is one of the main economic activities, has failed to provide minimum food requirements for the rapidly increasing population although the agriculture sector employs 90% of the labour force. Rainwater harvesting locally gather and stores rainfall through different technologies for going concern to meet the demands of human consumption or human activities. Rainwater harvesting's art has been practiced since the first human settlements. It has been a key entry point in local water management, buffering supplies of rainfall to service the human demand of freshwater. It includes the alteration of natural landscape water flows, it requires water managers to carefully consider the trade-offs. However, it can create multiple benefits even if it is offering synergies between different water demands and users at a specific location [6].

Fundamental parts such as (rainfall and soil water) of all terrestrial and aquatic ecosystems are which supply goods and services for human well-being. Availability and quality of water shows ecosystem productivity, both for agricultural and natural systems. There is a high demand on water resources for the development to maintain healthy ecosystems, which putting place water resources under pressure. When rain and soil water becomes scarce due to changes from wet to dry seasons cause ecosystem services to be suffer. Thus, Conservation of the environment and sustainable utilization of land and water resources have remained one of the major policy issues of concern in many developing regions [7]. Although Rwanda is known as an equatorial country with high rainfall, poor water management, low soil fertility, unreliable and erratic rainfall have continued to threaten food production in major arid and semi-arid regions of the country. Therefore in 2007, the government of Rwanda and non-governmental organizations introduced a national food security strategy based on the promotion and implementation of small scale irrigation. The initiative involved the introduction of RWH technologies at household level as an alternative intervention to mitigate the outcome of the erratic nature of rainfall in the arid and semi-arid parts of Rwanda for achieving the Millennium Development Goals of decreasing underdevelopment and poverty by reaching economic growth [5].

Ecosystem services are fundamental for human well-being. Our health, livelihoods and economies rely on well-functioning ecosystem services which range from provision of ambience and recreational opportunities to flood storage and pollution assimilation. Availability of water is critical for ecosystem health and productivity, ensuring supply of a range of products and services, to benefit human well-being (e.g., GEO4, 2017; MA, 2015). With growing multiple demands of water, the ecosystems supporting and regulating the structure and function of natural ecosystems may be eroding [8].

Rainwater harvesting is often implemented to improve local provisioning capacity by ecosystems for human well-being. However, as the landscape water balance is affected by increased rainwater harvesting, other services, in particular regulating services related to water abundance and availability, can be affected. Cultural services can be either negatively (if resources are diminished due to rainwater harvesting) or positively, depending on the local context. Rainwater harvesting is defined as a technique of collecting, storing and conserving rainwater for some productive purpose such as agricultural production, livestock rearing, household domestic consumption. Although rainwater harvesting techniques broadly include roof water harvesting, runoff harvesting, flood water harvesting and subsurface water harvesting [9].

For example found that adoption of rainwater harvesting in Ethiopia has a positive effect on value of crop production [10]. As a result of long history of agriculture and high population in Cyeza sector, vegetable cover is not significantly high. Consequently erosion problems in the step sloppy areas are enormous. Huge gullies are observed towards the part of Cyeza sector, where soils are totally removed beyond recovery. This is believed to have been aggravated due to the easily detachable nature of the soil. Soil erosion as one of components of regulating services, RWH ponds are need to mitigate soil erosion issues also act as in situ rainwater harvesting measures. Even though there were some efforts of soil and water conservation over the last years in Rwanda through the Ministry of Agriculture in Rwanda has embarked on an innovative project of building small water storage ponds for supplementary irrigation. This is an important step towards mitigating the effects of climate change (erratic rainfall) and using the available land to its full potential but these efforts are still limited.

Therefore, the following are the barriers that affect RWH ponds to not achieving its objectives that greatly impacted the ecosystem productivity in Rwanda: Here there is missing of real strategies for RWH, lack of skills and knowledge without different techniques for RWH, poor strategies for using water, a lot of water which is not usable, poor integrated management for harvesting run off water from the road networks, poor coordination and evaluation, increasing of population, useful of land without advanced technologies [11]. Malaria affects ecosystem productivity (crop production as one of component of provision service in ecosystem services) through the impairment of the health of the affected farm workers (i.e., through illnesses). Increasing the numbers of ponds and dams storing harvested rainwater in the landscape may increase the incidence of malaria, but if covered, or if water is stored underground, this may not impact incidence of malaria in the specific location of Cyeza sector. Therefore, the study aims to assess the impact that rainwater harvesting ponds have on ecosystem productivity in Cyeza sector of Muhanga District.

2. Methods and Materials

2.1. Description of Study Area

This study focused on the Muhanga district particularly in Cyeza sector, one of eight districts of southern province of Rwanda with 647.7 km^2 of the land surface and the population of 319,965 [12] population and housing census). The district is delimited by neighboring districts; in North by Gakenke District, in south by Ruhango District, in west by Ngororero District, in East by Kamonyi District. It has twelve Sectors: Cyeza, Kabacuzi, Kibangu, Kiyumba, Muhanga, Mushishiro, Nyabinoni, Nyamabuye, Nyarusange, Rongi, Rugendabali, Shyogwe. Its capital city is Nyamabuye sector. The district of Muhanga is subdivided into 12 Sectors, 63 Cells and 331villages (Imidugudu) with an estimated population of 319,965 people according to the Population and Housing Census (2012) confirming a population density of 493 inhabitants per km2 Women are 51% (163,772) and men 49% (155,193) of the total population estimates in the district [12].

2.2. Relief and Climate

Some part of Muhanga District is located in the "central plateau" of the country with topography of hills type. With high and low peaks, this part constitutes one of the best elements of the central "plateau" of the country. The other part constitute by the hills and high mountains of the Nil-Congo; it has peaks prancing beyond 2000 meters. The District is located in an area well watered, between 1100 mm and 1200 mm of altitude. The party enjoy two rainy seasons and two dry seasons and other short seasons of three months October, November and December another two months of dry season of January and February, there are also raining seasons from March to June and a long dry season from June to August or early September. The District is located mainly in the agro-bio- climatic region called "Granite Ridge". However, it has some peaks namely Budaha-Ndiza and buberuka [13].

2.3. Hydrographic Description

The District has the following large rivers: Nyabarongo which makes the District hydrographical belt (it crosses six sectors) and collects alone more than 90% of runoff/small rivers; Its tributaries are Miguramo, Muhanga, Ururumanza, Sagarara, Kiryango, Base, Akabebya, Mukunguri and pours into Akanyaru. In general, water is abundant in the District, especially in its northern part [13].

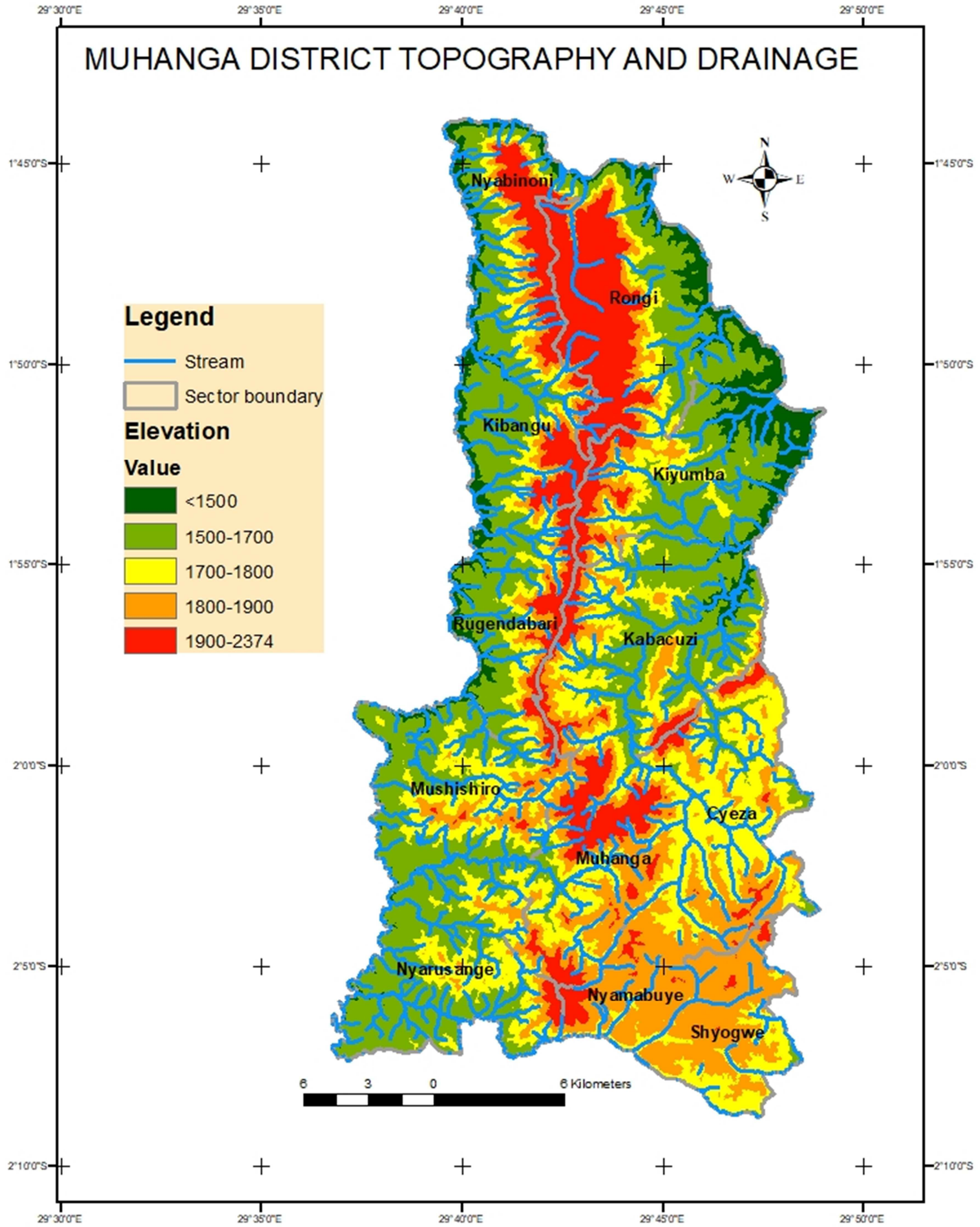


Figure 1. A map showing the location of the study area/Cyeza sector of Muhanga district.

3. Research Design

A research design is a plan and strategy of investigation conceived in order to obtain answers to research questions or problems. It is the complete scheme or program of the research [14]. For the present study, the research design was a qualitative case study but was supplemented with quantitative methods. Again, the design of the study is analytic in nature; the analytic research design is continuation of the descriptive research.

4. Data Collection and Analysis

4.1. Methods for Data Collection

Both primary and secondary data was collected and used to provide in-depth analysis of rainwater harvesting ponds impacts on ecosystem productivity.

4.1.1. Secondary Data Collection

Secondary data are data collected by someone other than the user. In other words, secondary data refers to data that have already been collected for some other purpose. Grinnell [15] defined secondary data as the data which already existing in books in same organization basements or hidden in the core of the computer. Secondary data was collected by use of already existing documents such as the main library of UNILAK, and other electronic resources.

A set of secondary data on ecosystem productivity was collected from RAB reports such as data on crop yields under RWH pond in MUHANGA district, land under irrigation, data on erosion control while data on rainwater harvesting ponds were collected from MINELA, RAB, TROCAIRE [16] and REMA reports.

Systematically, the secondary data was gathered by considering the facts that have already published in different documents as reports, books, papers, government policies and programs etc, which provide more details on the impact of rainwater harvesting ponds and ecosystem productivity in Rwanda [17].

4.1.2. Primary Data Collection

Primary data is data that is collected by a researcher from first-hand sources, using methods like surveys, interviews, or experiments. It is collected with the research project in mind, directly from primary sources.

Primary data was collected from farmers who use RWH ponds in Cyeza sector where the questionnaire was administered. Two main data collection tools were used: questionnaire and interviews. The sampling frame for the study was all farmers of the sector who adopted RWH ponds as the sampling unit.

For this study, as the researcher investigated on rainwater harvesting ponds and its impacts on ecosystem productivity, a sample from farmers were approached. The random sampling technique was employed to generate the sample. The sample of the farmers who use RWH ponds from Cyeza sector was calculated from its total population of 114.

A sample of 53 farmers was considered by using a formula attributed to Yamane. Our target population size is 114.

The sample size for this study was determined using the Yamane's formula; the formula used to determine the sample is written as following:

$$n=\frac{N}{(1+N(e)2}$$

Where: n=the total sample size,

N=total number of population

e=standard error or sampling error (0.1)

Total number of population (N) is 114

The sample was: $n=\frac{114}{1+114(0.1)2}=\frac{114}{2.14}=$ 53 informants

This sample of 53 respondents was approached in order to obtain primary data on crop production, soil erosion as components of provision and regulation of ecosystem services due to RWH ponds. The collection of these primary data was completed by using questionnaire and interview and laboratory analysis as described below. To make sure that the selection of 53 respondents were not be biased, the random sampling technique was employed to generate those key informants where each individual was chosen entirely by chance and each member of the population had an equal chance of being included in the sample.

4.2. Data Collection Procedures

4.2.1. Questionnaire

A questionnaire was used as the main data collection instrument to provide data that related to the objectives of the study. A questionnaire contains unstructured (open-ended) items given the qualitative orientation of the study whereby respondents were left free take time, think and then say their opinions and (closes-ended) questions which gives the respondent variety of choices to select. In this study, one set of questionnaire was administered, one to the general population selected in the sample size. Both open ended and closed ended questions were used. Mainly, closed-ended questions were preferred because it was guided the respondents within the scope of the content required. Open ended questions were used to supplement the closed ended questions and also give opportunity to respondent to express other issues which may not be captured in the choices. The questionnaire was given to the farmers who use RWH ponds in Cyeza sector.

The survey was conducted in a standardized interview by joining the respondents in their households and the investigation was beginning with the presentation. We were asked simple questions in the questionnaire and check according to the reply given by the respondent. These questions were accompanied by explanations if necessary. The questionnaire was written in English and then translated into Kinyarwanda to facilitate communication between the researcher and the respondent

4.2.2. Interview Guide

Much focus was agronomists and environmentalists. For this, the staff from District agricultural and natural resource unit, Rwanda Agriculture Board (RAB) was consulted in order to gain more understanding on the impacts of rainwater harvesting ponds on ecosystem productivity.

4.2.3. Laboratory Analysis

Laboratory analysis was physical and chemical analysis in nature. The one water sample was collected from the pond (Cyeza sector) which is used to irrigate crops in the area. The sample collected was kept in container that was thoroughly washed to avoid any contamination. The water sample collected was analyzed for pH, EC, TDS, Na, Ca, Mg, Ka, PO_4 and NO_3. All these elements were determined accordingly to international standards of laboratory analysis (WHO standards or permissible limits).

4.3. Data Analysis

After obtaining the required information from the questionnaire, the data was compiled, sorted, edited, classified and coded into a coding sheet and analyzed. This was done by analyzing closely the information given by each respondent in each questionnaire. The data was put in tables for easy of interpretation. The questionnaire data was analyzed in frequency and percentages. Descriptive statistics were followed to analyze the data collected using SPSS software, version 16.0. Water physical and chemical data obtained was subjected to statistical analysis. This was presented in tables and descriptive statistics to get the means, standard deviations, minimum and maximum values and regression analysis as was calculated using SPSS statistical software version 16.0.

5. Results and Discussions

5.1. Analyze the Quality of Water Used in the Ponds for Their Suitability in Ecosystem Viability

Table 1. The analytical results of physic-chemical parameters measured in water pond.

Location	Season	Parameters	Sample size	Min	Max	Mean
Cyeza sector	Wet	PH	1	5.3	6.7	6.0
		E. C	1	0.17	0.19	0.18
		TDS	1	102	125	113.5
		Calcium	1	89.4	91.5	90.4
		Mg	1	59.2	65.9	62.5
		HCO_3	1	95	180	135
		Sodium	1	112	121.2	116.6
		Po_4	1	0.60	0.82	0.71
		No_3	1	4.4	5.45	4.92

Source: RAB soil laboratory, 2019.

The results shown in table 1 are measurements of chemical analysis of pond water from Cyeza sector sampled in the wet season. The results show the minimum, maximum values, and their means for each parameter analyzed. The chemical analysis of this pond water sampled during the wet season was slightly acidic according to the pH (5.3-6.7). Therefore, PH of the ponds is analyzed to measure the acidity level of the water; this seems that the water also may be unusable for livestock watering as well as the water was considered to be acid for human consumption which result in health problems such as acidosis so the PH values were within the acceptable limit of WHO recommended of 6.5-8.5 for irrigation purpose and the electrical conductivity (EC) is the measure of the water capacity to convey electric current, it signifies the amount of total dissolved salts [18]. The EC of collected water sample from one pond in Cyeza sector location was within the range of 0.17-0.19 ds/m with a mean value of 0.18ds/m. These values were within the permissible WHO limits of (0.1-10) (WHO STD, 2011). Therefore, irrigation water with high ECw reduces yield potential. The study by Adam (20120 reported that surface runoff, minerals and salts from urban runoff during heavy rainfall contribute to high level of electric conductivity in the ponds, the high electrical conductivity could also be attributed to the levels of TDS because EC is a function of TDS which determines the quality of water [19].

The total dissolved solids concentration recorded ranged from 102-125 mg/l for pond sample. The level of TDS of the pond is within the acceptable standards (<1000 mg/l). The TDS indicate the salinity behavior of ponds water. Water containing more than 500 mg/l of TDS is not considered desirable for drinking.

The total hardness is a measure of calcium and magnesium concentration in water and is controlled by the source of the pond water. The values of total hardness obtained from the analysis varied from 89.4-91.5 mg/l with the mean value of 90.4 for calcium and 59.2-65.9 mg/l with the mean value of 62.5 for magnesium. The Ca and Mg concentrations are within the limits of WHO standards of <150 mg/l. This seems that the domestic fertilizers collection site could be the effect of the increase of calcium and magnesium to the water during rainfall period. The accumulation of these fertilizers through erosion enhance water pond to take more minerals, also liming activities could also increase the concentration of Calcium in pond water but are very crucial for plant growth and bicarbonate (95-180 mg/L) contents were found to be relatively high. However, continued use of this water for irrigation, may increase soil alkalinity due to its rich content in bicarbonate (137 mg/L) and relatively high soluble Ca and Mg elements which may precipitate as insoluble carbonates in soil and thus increase sodium content in soil solution. The sodium concentrations obtained were ranged from 112-121.2 mg/l. The values were within the permissible limits of WHO. For those mentioned above chemicals as calcium, magnesium, sodium or other chemicals could be increased by fertilizers and pesticides applied to the land surrounding a pond may occasionally reach the pond, especially on windy days or when heavy rain occurs shortly after application. Excessive concentrations are usually short lived, but they may result in aquatic organism kills, animal sickness, and plant injury if the pond water is used for irrigation. Insecticides are especially problematic and have occasionally caused aquatic organism kills in ponds. These problems are rare and short-lived but underscore the importance of careful use of pesticides in and around ponds.

The phosphate and nitrate concentrations recorded ranged from 0.60-0.82 mg/l for phosphate and 4.4-5.45 mg/l for nitrate concentrations. The phosphate concentrations were within WHO standard of 2.5mg/l. Phosphate may occur in surface water as a result of domestic sewage, detergents and farming fertilizers and high PO_4concentrations in the ponds could probably be attributed to the agro-chemical which was used to boost phytoplankton growth in the pond as they contain high concentration of phosphate [20]. The surface water contains nitrate due to leaching of nitrate with percolating water, water pond can also be contaminated by sewage and other wastes rich in nitrates.

5.2. The Level of Ecosystem Productivity in Cyeza Sector

Table 2. Rainwater harvesting ponds offer good crop yields to farmers.

	Frequency	Percent
Yes	40	75.5
No	13	24.5
Total	53	100.0

Source: Primary data, 2019.

As shown by table 2 among 53 farmers who adopted RWH Ponds, 40 informants represented by 75.5% of them testify that RWH ponds offer them good crop yields whereas the remaining of 13 farmers represented by 24.5% testify that RWH ponds do not provide them good crop yields. This implies that as rainwater harvesting ponds have significant impact on increasing crop yields in Cyeza sector as confirmed by the majority of the respondents in the table above.

Table 3. Extent to which RWH ponds provide crop productivity to growers.

	Frequency	Percent
Outstanding	20	37.7
Moderate	30	56.6
Poor	3	5.7
Total	53	100.0

Source: Primary data, 2019.

The table above shows that 37.7% of respondents stated that rainwater harvesting ponds provides crop productivity at outstanding or excellent level while 56.7% reported that they provide crop productivity at moderate level. This seems that RWH ponds are crucial components that enhance farmer's yields where are applicable during water scarcity period that enables farmers to have produce during previous season. This helps growers to be food secured and enables them to offer harvest to market that leads them to generate household incomes.

After evaluating farm yield from 1/4 ha of land that can be irrigated by a farm pond of 120 m^3, it was found that the average farm yields from fruits (both grafted avocadoes and lemons) is about 6.5 tones and farm yields from vegetables (tomatoes, cabbages) is about 19,250 fruits per year as shown in table 4

Table 4. Crops production of vegetables and fruits around pond site of 120 m^3.

Crops	Production per 0.25 Ha/ year	Remarks
Cabbages	3.5 tones	Cabbages to be productive after 6 months and this production is for 2 seasons
Tomatoes	3 tones	Tomatoes to be productive after 6 months and this production is for 2 seasons
Grafted avocadoes	8,000 fruits per 20 trees	Grafted avocadoes to be productive after 2 year and can produce during 4 years
Grafted lemons	11,250 fruits per 28 trees	Grafted lemons to be productive after 4 year and can produce during 5 years

Source: Primary data, 2019.

Table 5. Respondents agreements on domestic animals, watering domestic animals, water domestic consumption and household income earnings.

Responses	Agreement on domestic animals reared		Agreement for watering domestic animals		Agreement on pond water for domestic consumption		Agreement on household income earning	
	Freq.	%	Freq	%	Freq.	%	Freq.	%
Yes	50	94.3	1	1.9	0	0.0	40	75.5
No	3	5.7	52	99.1	53	100.0	13	24.5
Total	53	100.0	53	100.0	100.0	100.0	100.0	100.0

Source: Primary data, 2019.

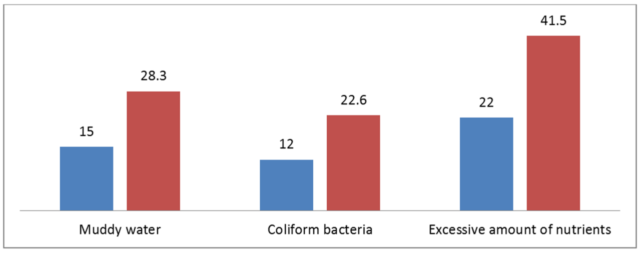
The table 5 depicts the respondent's agreements on domestic animals reared, watering domestic animals, water domestic consumption and household income earnings. As can be seen, 94.3% of respondents agreed that they raise domestic animals at their household level, 99.1% of respondents disagreed that they use pond's water for watering their domestic animals, 100% of respondents disagreed that they use pond's water for domestic consumption while 75.5% of participants stated that RWH ponds help them to earn household incomes. This implies that the fact that makes the RWH pond adopters to not use pond's water for watering their domestic animals is because of the pond's water are polluted where they contain some toxic nutrients that could affect animal heaths through deaths, water contamination resulting from wastes dumping by the roadside mechanic and residents living around the ponds could also cause water to become unhealthy. The reason also that makes households to not consume water from ponds is resulting from its toxicity via chemical nutrients that could be affect human health problems such as acidosis….., no quality of water ponds could also impact human health.

Table 6. Animal spaces reared by rural households in Cyeza sector.

	Frequency	Percent
Cows	15	28.3
Goats	10	18.9
Pigs	5	9.4
Chicken	10	18.9
Sheep	5	9.4
Rabbits	7	13.2
Fishes	1	1.9
Total	53	100.0

Source: Primary data, 2019.

The table above shows the animal spaces reared by rural households in Cyeza sector, the results indicated that the more of 28.3% raised cattle's, 18.9% raised both goats and chicken respectively, 13.2% raised rabbits and 9.4% raised both pigs and sheep respectively. This implies that the rural peasants of Cyeza sector have several kinds of domestic animals reared at household level, so that this was considered to see if the farmers use RWH ponds for watering their domestic animals so as was shown in previous table, the findings revealed that none of farmers who use pond's water for watering their animals, in the case of usage, could affect animal healths that might lead to humper the animal productivity (more of them could die, several diseases attack).



Source: Primary data, 2019.

Figure 2. The strategies used for protecting pond against water and air pollutants through climate regulation.

The figure above shows the perceptions of respondents on the techniques or strategies used for protecting pond against water and air pollutants through climate regulation, 56.6% reported that they fence the ponds against animal movement, 28.3% of farmers stated that they did intensive livestock as a way of reducing animal motions around pond location and others represented by 15.1% of informants reported that they adopted agroforestry system as a mean of reducing soil erosion in the ponds. This implies that following those mentioned strategies will protect the ponds against all water contaminants coming from external factors that could affect pond water quality.

The table 7 shows the perceptions of respondents on the crop productivity generated before and after adopting RWH ponds, the results showed that 98.1% of the respondents testified that before adopting that technology, the level of crop productivity was totally low, whereas after adopting RWH ponds, the findings showed that the level of crop productivity was increased from moderate to very high level represented by 52.8%, 37.7% and 9.5% respectively. This implies that crop productivity has been increased after adopting RWH ponds as shown in the table above.

Table 7. Crop productivity generated before and after adopting RWH ponds.

	Before adopting RWH ponds		After adopting RWH ponds	
	Frequency	Percent	Frequency	Percent
Low	52	98.1	0	0.0
Moderate	1	1.9	28	52.8
High	0	0.0	20	37.7
Very high	0	0.0	5	9.5
Total	53	100.0	53	100.0

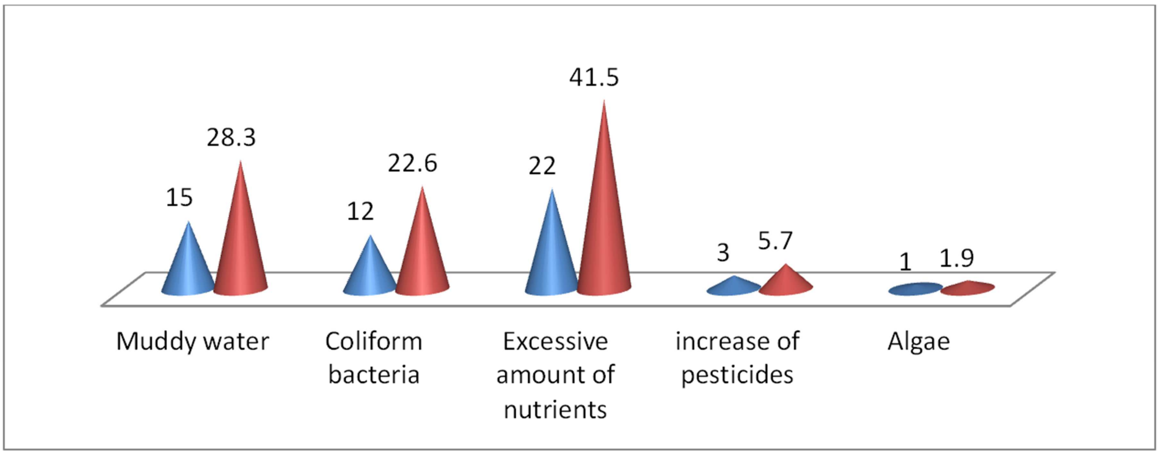
Source: Primary data, 2019.

Table 8. The strategies used for mitigating climate change issues as regulation services look for.

	Frequency	Percent
Afforestation	5	9.5
Intensive livestock	20	37.7
Reducing burning	21	39.6
Terracing	7	13.2
Total	53	100.0

Source: Primary data, 2019.

The table 8 shows the perceptions of respondents on the strategies used for mitigating climate change issues as regulation services look for. The results confirmed that 39.6% of farmers reduce burning activities, 37.7% of respondents reported that they avoid overgrazing activities through practicing intensive livestock, 13.2% stated that they adopt terracing activities, 9.5% of them said that they do afforestation. This implies that climate change problems were mitigated due to following those mentioned strategies above.



Source: Primary data, 2019.

Figure 3. Soil erosion effect to ecosystem productivity.

The figure above shows the effects that soil erosion have on the ecosystem productivity, the results assert that 41.5% of respondents reported that soil erosion increases the amount of nutrients inside water, 28.3% of respondents stated that soil erosion can increase muddy water via runoff from disturbed areas around the ponds, 22.6% of respondents testified that soil erosion can increase coliform bacteria inside the ponds, Some coliform bacteria will occur in all ponds, but dangerously high levels may occur in ponds that receive animal wastes from barnyards or wildlife or human wastes from septic systems, 5.7% of informants agreed that soil erosion might increase the pesticides in the ponds so that pesticides applied to the land surrounding a pond may occasionally reach the pond, especially on windy days or when heavy rain occurs shortly after application. Excessive concentrations are usually short lived, but they may result in aquatic kills, waterfowl death, animal sickness, and plant injury if the pond water is used for irrigation. Insecticides are especially problematic and have occasionally caused fish kills in ponds. These problems are rare and short-lived but underscore the importance of careful use of pesticides in and around ponds. This seems that soil erosion could affect more serious effects for ecosystem productivity where some living organisms should die due to high toxins received in the ponds.

5.3. Rainwater Harvesting Ponds Can Increase Ecosystem Productivity in Cyeza Sector

Table 9. RWH ponds have a great impact on the ecosystem productivity in Cyeza Sector.

	Frequency	Percent
Strongly agree	48	90.6
Agree	4	7.5
Disagree	1	1.9
Strongly disagree	0	0.0
Total	53	100.0

Source: Primary data, 2019.

The table depicts that RWH ponds have a great impact on the ecosystem productivity, the results show that 90.6% of participants were strongly agreed that rainwater harvesting ponds can increase the ecosystem productivity in Cyeza sector. Rain water harvesting ponds have significant impacts and RWH ponds promote agricultural development through used for irrigation purpose in different district of Eastern province namely Nyagatare, Gatsibo and Kayonza district [21].

Table 10. Correlation between rainwater harvesting ponds and ecosystem productivity.

Variables		Rainwater harvesting ponds	Ecosystem productivity
Spearman's correlation Rainwater harvesting ponds	Correlation coefficient	1.000	.886**
	Sig. (2-tailed)		.000
	N	53	53
Ecosystem productivity	Correlation coefficient	.886**	1.000
	Sig. (2-tailed)	.000	
	N	53	53

**. Correlation is significant at the 0.01 level (2-tailed).

The table 10 above shows the degree of correlation between rainwater harvesting ponds and ecosystem productivity. The statistical evidences depict that there is a relationship between rainwater harvesting ponds and ecosystem productivity with a degree of correlation equal to 0.886 interpreted as positive and very high correlations. The study aims to accept null hypothesis stating that there is no decrease of ecosystem productivity due to rainwater harvesting ponds and reject alternative hypothesis stating that the use of rainwater harvesting ponds has no impact on the ecosystem services (provision and regulation). The study concludes that rainwater harvesting ponds increases ecosystem productivity in Cyeza sector.

5.3.1. Regression Analysis

In regression analysis, there are two types of variables, dependent variables and independent variable. The variable which influences the values of other variables is called independent variable; whereas the variable whose value is influenced by independent variable is termed as dependent variables [22]. The variables of this study are rainwater harvesting ponds as independent and ecosystem productivity as dependent variable of this study.

5.3.2. Linear Regression Analysis

Linear Regression analysis is a set of statistical methods used for the estimation of relationships between a dependent variable and one or more independent variables. It can be utilized to assess the strength of the relationship between variables and for modeling the future relationship between them.

Linear regression analysis equation:

$Y= a +bx_1 +bx_2+bx_3+bx_4+e$ Where, Y – dependent variable, X – independent (explanatory) variable

Table 11. Table of regression coefficients.

Model	Unstandardized coefficients / Standardized coefficients			T	sig.
	B	Std Error	Beta		
Constant	5.809	.553	-	3.155	.005
Water availability	0.563	.182	.438	3.722	.018
Water quality	0.820	.165	.703	2.043	.0145

From the data in shown in table above, the established regression equation was $Y=5.809+0.563X_1+0.820X_2$. The results of the regression model show that, taking all independent variables (water availability and water quality) constant, ecosystem productivity was 5.809. It was established that, taking other independent variables constant, water quality contributes at 56.3% in increasing ecosystem productivity while water quality contributes at 82% in promoting ecosystem productivity. By concluding, it implies that Cyeza sector has farmers who adopted RWH ponds which have a great impact or contribution in increasing ecosystem productivity.

6. Conclusion

The study is entitled the impacts of RWH ponds on the ecosystem productivity in Rwanda. The objectives of this study were to analyze the quality of water used in the ponds for their suitability in ecosystem viability, to assess the level of ecosystem productivity in Cyeza sector and to determine how rainwater harvesting ponds can increase ecosystem productivity in Cyeza sector. From the results of this study, the following conclusions were reached: the chemical values of water sampled were within the limits acceptable for irrigation and crop production as indicated by WHO, the farmers agreed that RWH ponds offer good yields to them and others confirmed that soil erosion affects ecosystem productivity negatively and the study concludes that water quality contributes at 56.3% in increasing ecosystem productivity while water quality contributes at 82% in promoting ecosystem productivity implying that Cyeza sector has farmers who adopted RWH ponds which have a great impact or contribution in increasing ecosystem productivity.

Finally, technology of RWH pond must be rainfall areas in order to maximize the interest of them. The forecast to the change of climate it will add rainfall existing and evaporation, and also increase of people will require the ecosystem services, especially for water. Depending on rainwater harvesting will be a key for combating and reducing vulnerabilities. Therefore we need to use rainfall as significant tools for managing resource from water management policies, rainfalls can be used as tools for land conservation for better living of citizens as well as land productivities [23].

Author Contributions

Dr. Abias Maniragaba guided and supervised this research. Kirabo Justine designed the Study and performed the analysis and made discussion of the study results.

Conflicts of Interest

The author declares no conflict of interest.

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