

Rainwater Harvesting Systems (RWHS): The Multi-Level Perspective towards Sustainability Transition

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Abstract. Water scarcity, severe flooding, environmental concerns, and the drive for sustainability have positioned rainwater harvesting systems (RWHS) as a key element in sustainable resource management. However, overcoming adoption challenges remains crucial. This study investigates the potential of RWHS to address water scarcity and flooding in the City of Koronadal, Philippines, using Frank Geels' Multi-Level Perspective (MLP) framework and Jan Rotmans' Sustainability Transition concepts. Through surveys, interviews, and document analysis, the study examines the interplay of landscape pressures (such as climate change, water scarcity, and national laws on climate change and resource management), socio-technical and political regimes (including existing water management practices, local policies, and regulatory frameworks), and technological niches in shaping the city's water future. The findings reveal that although awareness of water scarcity and climate change is high, RWHS adoption is hindered by a lack of policy support, financial constraints, technical limitations, and institutional barriers. The study also identifies opportunities for RWHS to alleviate flooding, reduce reliance on traditional water sources, and promote sustainable water management. The research concludes by proposing a comprehensive implementation scheme for RWHS in Koronadal City. This scheme integrates policy interventions, financial incentives, technical support, and community engagement to overcome existing barriers and facilitate a transition toward a more resilient and water-secure future.

Keywords: Rainwater harvesting systems; Optimization study; Resource management; Multi-level perspective; Transition management; Sustainability transition.

1.0 Introduction

Research done by government agencies, environmental groups, and the Asian Development Bank (ADB) claimed that the Philippines within the next decades may experience a looming water crisis (Asian Development Bank, 2016; World Bank, 2019). Despite being archipelagic, the country may experience potential water scarcity for drinking, sanitation, agriculture, and industrial uses within the next ten years. Unless stronger management and conservation efforts through state policies are initiated, such as slowing the demand to match the rate at the country's water resources are replenishing, supporting and adopting technologies such as Rainwater Harvesting Systems (RWHS) to serve the needs for irrigation and domestic uses without pumping out from municipal waters that are reserved for clean drinking water can be of great relief. The National Water Resources Board (NWRB) has also highlighted the growing water stress in the country, particularly in urban areas experiencing rapid population growth and industrialization (NWRB, 2015). The situation is further exacerbated by climate change impacts, such as changing rainfall patterns and increased frequency of droughts (Lasco et al., 2018).

These findings underscore the urgency of implementing stronger water management and conservation efforts through state policies. Slowing down the demand for water to match the rate of replenishment of the country's

water resources is crucial. Moreover, supporting and adopting technologies like Rainwater Harvesting Systems (RWHS) can significantly alleviate the pressure on municipal water supplies, ensuring adequate water for irrigation and domestic uses (Imteaz et al., 2014). Thus, effective water management is crucial to ensure its availability and quality for human consumption and other essential uses.

Aligned with the urgency of achieving the UN's Sustainable Development Goals (SDGs) for Clean Water and Sanitation (SDG 6), Sustainable Cities and Communities (SDG 11), and Climate Change Actions (SDG 13), an Optimization Study of Rainwater Harvesting Systems (RWHS) was undertaken in Koronadal City. This study explores the potential for adopting sustainable water management practices to address these critical global challenges.

Frank Geels' Multi-Level Perspective (MLP) as an analytical tool was used to assess how technological niches such as RWHS can influence the socio-political regimes and eventually change the landscape of climate change and limited water resources. This framework offers a valuable lens for analyzing sociotechnical transitions and theorizes transitions as non-linear processes driven by the interplay between three analytical levels. At the niche level, radical innovations emerge and develop, often challenging the status quo of the existing system. These innovations are nurtured and protected within niche spaces that provide a supportive environment for experimentation and development.

With these issues regarding environmental resources and natural phenomena, several laws and policies have already been issued by the government to address the predicament of mitigating the changing weather patterns and the adverse effects of climate change, including the scarcity of clean drinking water resources. These laws and policies include the Republic Act 6716 (an act providing for the construction and rehabilitation of adequate potable water supply to be made conveniently available to every barangay in the country and was made obtainable last March 17, 1989), the Philippine Green Building Code, Climate Change Act of 2001 and the DILG Memorandum Circular No. 2017-76 (policies and guidelines for the construction of rainwater collectors issued last June 2017). However, have these laws and policies been adopted, implemented in localities, gained legitimation from the public, and influenced the landscape of climate change and scarcity of water resources? How can optimal system sizing be achieved when adopting a rainwater capture or harvesting system in a specific area with a given climate characteristic?

Hence, this paper determined the optimum volume of collection tanks for RWHS in households as well as its economic feasibility, answered the question of what the current efforts and factors that impede the mainstreaming and adoption of RWHS to be included as part of the day-to-day activities that involve the usage of water, searched the elements that inhibit the implementation of the above-mentioned policies and recommends for solutions in the form of policy recommendations to encourage the needed technology modifications, and significantly to manage the limited water resources, excessive flooding and combat other negative effects of a changing climate. Also, this study can guide sustainability transitions in the chosen study site. This study was conducted with the motivation to examine the role of socio-political and socio-technical regimes as the driving forces to the mainstreaming of Rainwater Harvesting Systems as a practical option for water resources management and climate change adaptation using key concepts of Transition Management and Frank Geels' Multi-Level Perspective (MLP) and further propose a policy for adopting the RWHS technology or improving current policies associated with the technology for endorsement to the Local Government Unit of the City of Koronadal.

2.0 Methodology

2.1 Research Design

This study employed mixed-methods (archival, quantitative, and qualitative) research designs to attain its main objective of shaping effective policies and strategies for mainstreaming RWHS. The optimization study to determine the viability and sustainability of RWHS is archival research. The empirical relationship method was used to determine the optimum rainwater tank capacity through statistical analyses. Rainwater collection and usage were projected based on historical data and predict system behavior under different scenarios using the collected data for rainfall, different RWHS design specifications (storage capacity and catchment area), and water usage patterns. Relationships of dependent and independent variables were then analyzed using regression.

One of the objectives of this research is to know the elements that impede the implementation of RWHS incorporation in households and buildings in a locality thus, this study carried out a Sequential Research Method Convergent parallel design, also known as concurrent mixed methods, is a research design where both qualitative and quantitative data are collected simultaneously and then analyzed separately. The results are then merged and interpreted to provide a comprehensive understanding of the research problem (Creswell & Plano Clark, 2018), and eventually develop a more thorough understanding of the factors that might influence the perceptions and willingness of the respondents in the mainstreaming of RWHS.

2.2 Research Locale

The area of study, the City of Koronadal which is composing 27 barangays, is the capital of the province of South Cotabato and the regional administrative center of Region XII. The city is a fast-developing growth center with a total land area of 277 square kilometers, a tropical rainforest climate, and a population of 195,398 according to the Philippine Statistics Authority (PSA) 2020 census. For the survey of the willingness to adopt RWHS, this study was specifically conducted in barangays with housing units within subdivisions, and commercial and industrial housing units in the City of Koronadal namely: Carpenter Hill, Concepcion, Morales, Paraiso, San Isidro, Sta. Cruz, Sto. Niño, Zone II, Zone III, and Zone IV.

2.3 Research Participants

For the archival research and document analysis, data were gathered from the concerned offices in the city government of Koronadal, including the Philippine Statistics Authority and the City of Koronadal Water District.

Key Informant Interviews (KIIs) with key players were thoroughly conducted with the City's Local Chief Executive (LCE), and committee chairs on the environment and infrastructures about their current efforts for the upgrading or advancement of existing laws and regulations for the adoption of Rainwater Harvesting Systems (RWHS). The City Architect who also functions as the Building Official, the City Engineer, and the City Environment and Natural Resources Officer were interviewed about their current efforts in implementing corresponding laws and regulations for the adoption of Rainwater Harvesting Systems (RWHS) with a discussion on what they perceive as the difficulties at their level in carrying out the rules and regulations, if any, on the implementation of rainwater harvesting in an urban setting.

For the household survey, a total of 48,209 housing units of which 22% constitutes the subdivisions and commercial/industrial housing units, according to the 2020 Philippine Statistics Authority Census obtained through the City Planning and Development Office were only considered based on the set criteria (floor area and availability of gutter system). Using Slovin's Formula with 48,209 housing units as the total population (N), 5% margin of error, and 95% confidence interval, a minimum of 397 sample size was recommended. However, due to time and budget constraints, 22% of the 397 sample sizes were surveyed, constituting 88 housing units. These 88 respondents were prorated to the ten (10) barangays with housing units within subdivisions, and commercial and industrial housing units in the study area based on the data obtained from the City Assessor's Office through the City Planning and Development Office.

2.4 Research Instrument

This study used adopted, modified, and validated guide questions and survey questionnaires as the main instruments and primary data sources to answer the research questions relating to Frank Geels' multi-level perspective and Rotmans' sustainability transition concepts. Ethical guidelines were considered in this study, and respondents' participation was voluntary. To validate the instruments and ensure that the study objectives were met, experts assessed and reviewed the interview guide and survey questionnaires. Secondly, a preliminary test involving a small number of participants was conducted to pinpoint any unclear phrasing in the guide questions for KII and questionnaire for the survey, and also to evaluate the overall clarity and thoroughness of the research tools.

In the Key Informant Interviews, the researcher adopted, modified, and underwent the validation of instruments by the experts. The interview guide used determined the key informant's awareness of the challenges of climate change, the current policy context for water resources management, perceptions of RWHS, compliance with existing laws, regulatory framework, and technological advancements.

Survey questionnaires were used for households to examine their extent of awareness about the system and their level of willingness to adopt. The questionnaires also determined what factors will influence the respondents' willingness to adopt RWHS, what kind of support or incentives would encourage them more to adopt RWHS (for reference in the formulation of policy recommendation), and demographics such as age, gender, and estimated annual income.

2.5 Data Gathering Procedure

This study used the steps shown in Figure 1 below to collect data. Approval of the Dean of the Graduate School was first secured before the researcher distributed the Request Letters to the concerned offices and the Office of the City Mayor, the researcher was then endorsed by the concerned. Next, interviews were conducted with the research participants using the interview guide questions.

For the household survey, a Permit to Conduct was received by the concerned barangay, then a consent form was initially filled up by the respondents before answering the survey questionnaires. The researcher briefly explained to the respondents how each research questionnaire was completed and immediately collected it. Lastly, the researcher assured the respondents that all their responses would be kept strictly confidential and that the study's findings would only be used for academic and educational purposes.

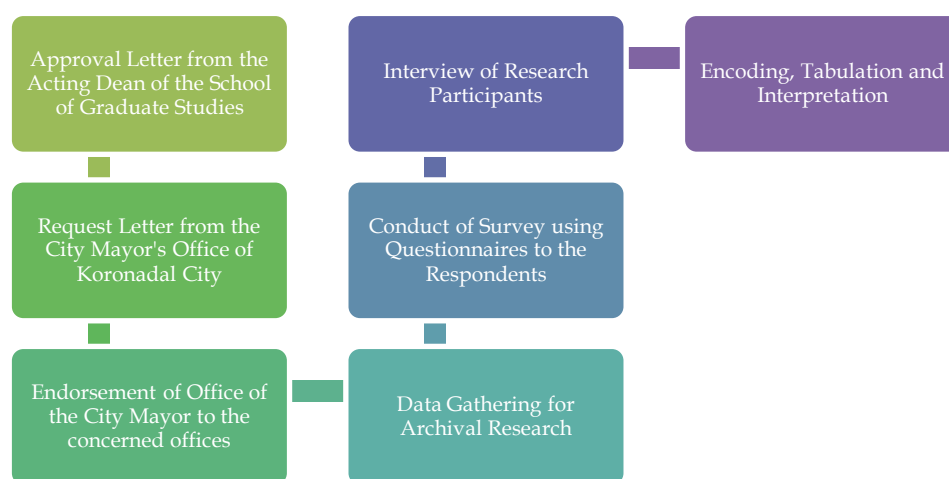


Figure 1. Data gathering procedure

2.6 Ethical Considerations

This research study followed ethical guidelines. To prevent permanent or excessive harm to the respondents of the household survey and key informant interviews, ethical considerations were observed. All participations were voluntary, participants were informed of the objectives of the study and other details related to the study before the conduct of the activities. Consent forms were attached to the first part of the questionnaires, and enumerators were trained to explain and translate questions in vernaculars if necessary. Lastly, anonymity and confidentiality of the data were observed.

3.0 Results and Discussion

3.1 Technical and Economic Factors

Determination of Optimum Rainwater Tank Capacity

Ten-year rainfall data (2014-2023) collected from the Automated Weather Station (AWS), average roof area of 64.4 square meters, and average water consumption per household were collected and analyzed using the empirical relationships method.

Table 1. Tank capacity test for efficiency

Rainfall Year	Tank Capacity, %					
	0.50 m ³	1.0 m ³	2.0m ³	3.0 m ³	4.0 m ³	5.0 m ³
2014	21.53	44.69	76.30	94.79	113.50	113.50
2015	20.30	40.27	82.41	133.10	183.53	240.94
2016	21.70	45.88	93.30	137.96	155.08	160.68
2017	23.38	46.84	92.03	105.11	105.11	105.11
2018	19.47	39.74	82.10	119.17	135.38	155.64
2019	21.65	47.55	98.67	145.35	174.23	195.02
2020	21.20	43.79	98.67	157.23	205.66	230.66
2021	26.29	59.36	134.56	219.73	295.77	373.27
2022	28.83	54.90	102.25	144.60	178.95	197.13
2013	19.11	40.06	81.94	128.49	173.52	216.51
Average	21.53	44.69	76.30	94.79	113.50	113.50

A test for efficiency by tank capacity shows that 2.00 cubic meters for storage is the most efficient (94.22%) tank size for household level in the City of Koronadal which depicts a linear relationship expressed in equation 1. The tank efficiency in collecting rainwater increases as the tank capacity increases. Efficiency of more than 100% means an excess of rainwater collected to the average water demand of the household. The percentage nearest to 100% is considered to be the most efficient.

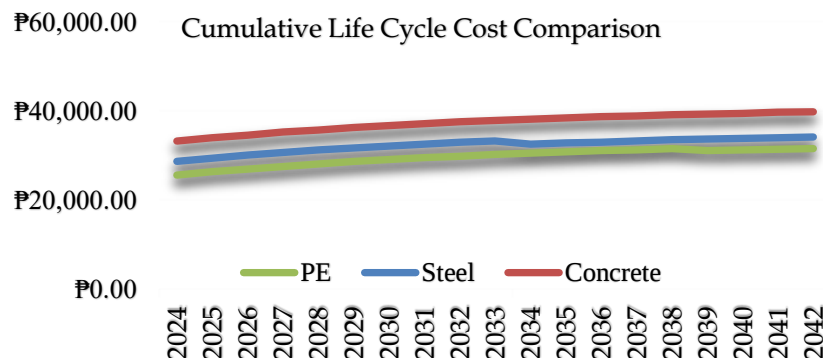
$$y = 39.926x + 8.9167$$

Eq (1)

Cost and Benefit Analysis

Table 2. Benefit-cost ratio of 2.00 cu.m capacity tank for different materials

Material	Indicator					
	Economic NPV @10%	EIRR	Payback Period	NPV of Project Benefits	NPV of Project Costs	BCR
PE	₱53,409.46	266.65%	1.02	₱199,880.12	₱166,458.67	1.20
ST Steel	₱33,949.46	59.59%	1.14	₱166,477.74	₱149,176.06	1.12
Concrete	-₱2,126.87	9.25%	1.33	₱220,566.69	₱244,750.23	0.90

**Figure 2.** Life Cycle Cost Comparison of PE, Steel, and Concrete

Based on the results of the Benefit-to-Cost Ratio and Life Cycle Cost Analysis, Polyethylene (PE) material is the most cost-effective alternative material in the long run, while concrete material is the least. Even if the initial investment for the concrete material is lower, the recurring costs over its lifespan might outweigh the initial savings on the PE and stainless steel. With the current landscape, ample benefits can be added for the economic analysis of installing RHWS in the Koronadal City setting given its location, rainfall pattern, and existing urban design. The allure around RWHS shouldn't solely focus on its economic and financial benefits- but it is essential also to highlight the positive benefits such as increased self-reliance, increased quality of living, and environmental sustainability to generate broader appeal that would add to the society's willingness to pay or the public and private institutions' willingness to invest.

3.2 Institutional Factors

Current Efforts and Difficulties in Mainstreaming RWHS in the Socio-political and Socio-Technical Regime

The collective outcome of the data gathering with key informants consists of a theme with four main branches shown in Figure 3 below: Lack of Local Policies, Implementation Challenges, Benefits and Applications of RWHS, and Proposed Solutions and Strategies.

Lack of Local Policies includes sub-themes such as the lack of local regulations, the general absence of policies, and compliance with national standards but insufficient local strategies. Connections include linking the lack of local regulations to the absence of local ordinances and the need to integrate water management policies.

Implementation Challenges cover the absence of local ordinances, lack of technical manpower, coordination and political influence, high costs and budget prioritization, social perceptions and practices, and lack of information, education, and communication (IEC). Connections include linking the absence of local ordinances to the lack of local regulations, lack of technical manpower to public relations and community engagement, high costs to financial incentives, social perceptions to community awareness, and IEC to public relations and community engagement.

Perceived Benefits and Applications of RWHS include flood reduction and runoff management, domestic and household use, irrigation and urban agriculture, and community awareness and water conservation. Connections include linking flood reduction to proposed solutions for promoting RWHS, domestic use to the need for local ordinances and regulatory requirements, irrigation to integration of water management policies, and community awareness to public relations and community engagement.

Proposed Solutions and Strategies to integrating water management policies, regulatory requirements in building permits, local ordinances for RWHS, financial incentives, and public relations and community engagement through IECs. Connections include linking integration of water management policies to the general absence of policy frameworks and irrigation, regulatory requirements to compliance with national standards and domestic use, local ordinances to the absence of local frameworks, financial incentives to high costs, and public relations and community engagement to lack of technical manpower, IEC, and community awareness.

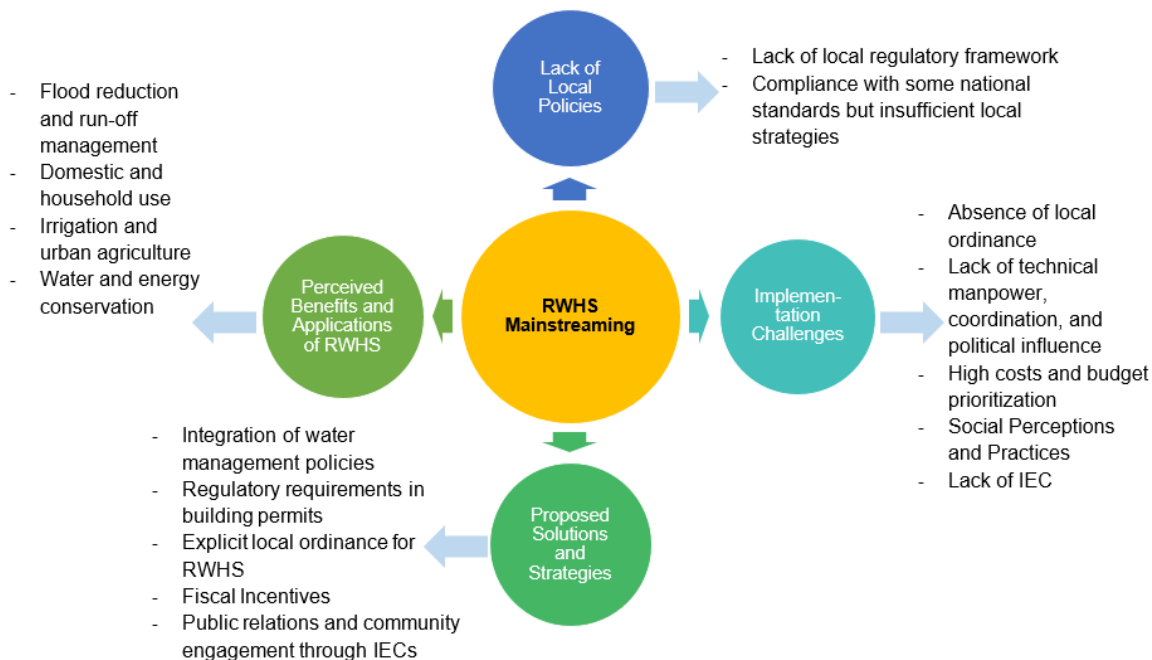


Figure 3. Central Themes for RWHS Mainstreaming in the City of Koronadal

3.3 Social Factors

Willingness to Adopt RWHS and Factors Influencing RWHS Adoption

A total of 88 respondents were surveyed to examine their level of awareness and extent of willingness to adopt RWHS. Most respondents are 31-45 years old (45.50%), and 18-30 years old (44.30%). The remaining 10.20% belongs to ages 46 and above. Respondents consist of 39 males and 49 females whose estimated income are categorized as shown in the table below. Most respondents have an estimated annual income of P150,000.00 (39.80%), followed by P150,000.00 - P300, 000.00 (31.80%). The average income level is 2.24 (on a scale of 1 to 6), with a standard deviation of 1.493. This suggests a relatively wide range of income levels among respondents.

The result shows that out of the 88 respondents, 67 (76.10%) expressed their very high willingness to adopt or install RWHS. Fourteen (14) respondents expressed a high willingness while four (4) answered neutral. Two (2) respondents had a low willingness to install, and one (1) respondent expressed a very low willingness to install. The mean value of the respondents' willingness to adopt is 4.636 which suggests that they have generally a very high willingness to install. The standard deviation is 0.776, which indicates that while most respondents are highly willing, there's still some variation in their responses

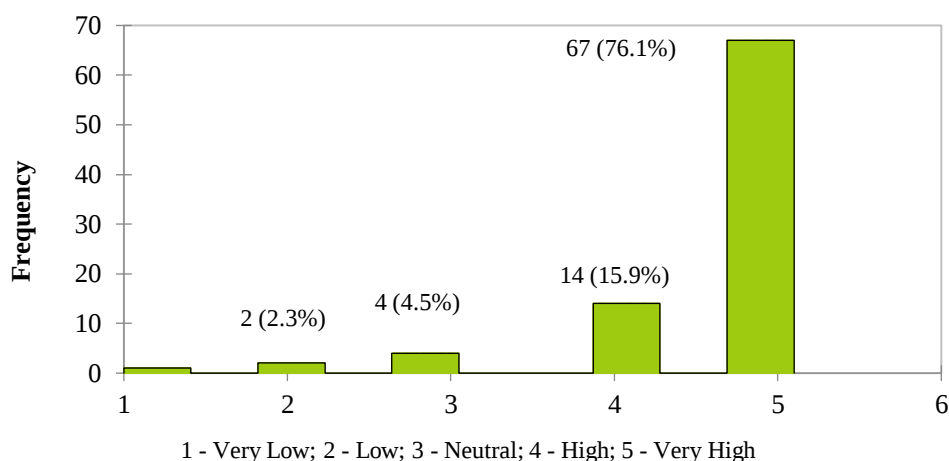


Figure 4. Willingness to install RWHS

A correlation of the respondents' willingness to adopt RWHS to their awareness of water scarcity as a pressing issue and the significance of the adverse impact of climate change, especially flooding was performed. The relationship between the variables is measured using the Spearman rank correlation since the distribution of values for these two variables is not normal. As per results using the Kolmogorov-Smirnov test with a sample size greater than 50, the exploratory part shows that the distribution is not normal, hence the use of Spearman rank correlation.

Table 3. Summary statistics of variables

Variable	n	Mean	SD	Description
Extent of water scarcity as a pressing issue	88	3.920	1.215	High
Significance of the perceived impacts of climate change on water resources	88	4.273	1.025	High
Willingness to install RWHS	88	4.636	0.776	Very High

For the variables Extent of water scarcity as a pressing issue and the Significance of the perceived impacts of climate change on water resources, a multiple R of 0.71 indicates a strong positive correlation which means that as the perception of water scarcity as a pressing issue increases, so does the perception of the significance of climate change impacts on water resources. In other words, people who strongly feel water scarcity is a problem also tend to believe climate change is significantly impacting water resources. An R² of 0.5 means that 50% of the variation in the perceived significance of climate change impacts can be explained by the extent of water scarcity. P-value

0.41 is relatively high, indicating that the observed correlation might not be statistically significant. More data may be needed to confirm this relationship.

For the variables “Extent of water scarcity as a pressing issue” and “Willingness to Install RWHS” multiple R of 0.079 indicates a very weak positive correlation. There's a slight tendency for those who perceive water scarcity as a problem to be more willing to install RWHS, but the relationship is negligible. An R^2 0.006 means that only 0.6% of the variation in willingness to install RWHS can be explained by the extent of water scarcity. The P-value of 0.000058 indicates a very low p-value which suggests that this weak correlation is statistically significant, meaning it's unlikely to be due to chance.

For the variables “Significance of the perceived impacts of climate change on water resources” and “Willingness to install RWHS”, a multiple R of 0.184 indicates a weak positive correlation. People who perceive climate change as having a significant impact on water resources are slightly more willing to install RWHS. An R^2 of 0.034 means only 3.4% of the variation in willingness to install RWHS can be explained by the perceived significance of climate change impacts. The P-value of 0.0000007 is an extremely low p-value which strongly suggests that this weak correlation is statistically significant.

Hence, the strongest relationship is between the perception of water scarcity and the perceived impact of climate change on water resources. The relationship between these perceptions and the willingness to install RWHS is weak but statistically significant, suggesting other factors may be more influential in the decision to install RWHS.

Table 4. Correlation matrix of variables

Variables Correlated	R	R_s	P-values	Extent of Relationship	Remarks
“Extent of water scarcity as a pressing issue” and “Significance of the perceived impacts of climate change on water resources”	0.710	0.50	0.41	Strong Positive	Not Significant
“Extent of water scarcity as a pressing issue” and “Willingness to Install RWHS”	0.079	0.006	5.8×10^{-5}	Weak Positive	Significant
“Significance of the perceived impacts of climate change on water resources” and “Willingness to install RWHS”	0.184	0.034	7×10^{-7}	Weak Positive	Significant

Correlation analysis was further conducted to explore the relationships between the factors affecting respondents’ decision to install or adopt RWHS, revealing patterns of association and potential multi-collinearity. Principal Component Analysis (PCA) was applied to the standardized data to reduce the dimensionality and identify underlying factors that explain the variance in the data. The number of components to retain was determined based on the scree plot and the Kaiser criterion (eigenvalues greater than 1).

The component matrix (factor loadings) was examined to identify the variables that loaded strongly onto each component and were labelled based on the common themes among the associated variables. The total variance explained by each component was assessed to determine their relative importance. The PCA results were validated by comparing them with the initial correlation analysis and the qualitative findings from the interviews. The interpretation of the components was refined based on the context of the study and the existing literature on RWHS adoption. The final PCA results revealed three distinct components that explained a significant portion of the variance in the data. These components were interpreted as the representations of environmental concerns, technical considerations, and financial aspects of RWHS adoption. The component matrix provided insights into the specific variables that loaded strongly onto each component, revealing the underlying factors influencing RWHS adoption decisions.

Table 5. Principal component analysis matrix

Variables	Component Matrix		
	1	2	3
Estimated Annual Income	-.437	-.048	-.456
Extent of water scarcity as a pressing issue in Koronadal City	.743	.366	.247
Significance of the perceived impacts of climate change on water resources	.645	.415	.444
Willingness to install RWHS	.131	.301	.235
What would be the most important factors influencing your decision to adopt RWHS? (Please rank the corresponding factor, with 1 as the most important):			
[Cost]	-.745	-.067	.380
[Ease of Installation and Maintenance]	-.737	.305	.202
[Reliability and Effectiveness of the System]	.248	.669	-.637
[Potential Water Savings and Cost Reduction]	.685	-.500	.089
[Environmental Benefits]	.796	-.312	-.214

Each column (1, 2, 3) represents a principal component. These are new, uncorrelated variables created as linear combinations of the original variables. They capture different aspects of the original data. Each row represents one of the original variables from the survey data. The numbers in each cell are the factor loadings which show the correlation between each original variable and each component. The absolute value of the factor loading tells how strongly the variable is associated with the component. Higher absolute values mean a stronger association. The sign (positive or negative) tells the direction of the relationship. A positive sign means the variable and component increase together, while a negative sign means the variable increases as the component decreases.

Table 6. Interpretation of component matrix using principal component analysis

Component	Key Variables (High Loadings)	Interpretation	Target Audience for RWHS Promotion
1	Extent of water scarcity, Climate change impact, Potential savings, Environmental benefits (all positive); Cost, Ease of installation (both negative)	Concerned about water scarcity and environmental impact; Less concerned about cost and maintenance.	Emphasize the environmental and long-term financial benefits of RWHS.
2	Reliability and effectiveness (positive); Potential savings (negative)	Prioritize system reliability and effectiveness over cost savings; Maybe more receptive to technical information and demonstrations of RWHS performance.	Highlight the technical aspects and proven reliability of RWHS.
3	Cost (positive); Reliability and effectiveness, Environmental benefits (both negative)	Primarily concerned about cost; May be willing to compromise on system performance and environmental impact for affordability.	Focus on affordability, low-cost options, and potential long-term savings.

The factors influencing the decision of the respondents to adopt RWHS are multifaceted including environmental concerns, technical considerations, and financial aspects. Different individuals prioritize these factors differently, leading to the distinct components identified in the analysis.

To promote RWHS adoption, strategies should be tailored to address the concerns of each group categorized by each component: (1) Environmentalists: Emphasize environmental benefits and long-term cost savings; (2) Rationalists: Highlight the system's reliability and ease of use; and (3) Budget-conscious: Focus on affordability and potential cost reductions.

“Willingness to Install RWHS” doesn't weigh strongly on any specific component, suggesting that it is influenced by a complex mix of factors thus this variable requires further investigation to understand its drivers more fully.

“Estimated Annual Income” also doesn't load strongly, indicating that income level alone might not be a major predictor of RWHS adoption attitudes in this particular dataset.

Thus, while the respondents' willingness to adopt RWHS is high, the decision to install rainwater harvesting systems (RWHS) is complex and not solely driven by income or the perceived urgency of water scarcity and climate change. While these landscape-level pressures exist, they haven't been strong enough to overcome the barriers to adoption, which include a lack of awareness, high costs, installation complexity, water quality concerns, regulatory hurdles, limited government support, resource constraints, and infrastructure limitations such as space.

3.4 Summary

This study reveals that for technical and economic factors, a volume of two (2) cubic meters for storing rainwater is the optimum for household level with an average roofing area of 64.4 square meters. Using polyethylene as a tank material is the most viable compared to stainless steel and concrete materials. Performing the cost and benefit analysis based on the design considerations and assumptions used for this study, indicators used show that the financial costs of implementing RWHS can outweigh the monetary benefits that could be derived from it. This means that from a purely financial perspective, the investment in RWHS may not be justified. Nonetheless, the allure around RWHS shouldn't solely focus on its economic and financial benefits but it is essential also to highlight the positive benefits such as increased self-reliance, increased quality of living, and environmental sustainability to generate broader appeal that would add to the society's willingness to pay or the public and private institutions' willingness to invest. Ward et al. (2015) found that while financial incentives are important, non-monetary benefits like environmental consciousness and water security also play a significant role in RWHS adoption decisions, while Ghofrani et al. (2013) in their overview of RWHS technologies, highlight the broader environmental benefits of RWHS, including reduced stormwater runoff and improved groundwater recharge.

The research findings indicate that the adoption of Rainwater Harvesting Systems (RWHS) in Koronadal City is influenced by a complex interplay of factors. While there's awareness of water scarcity and climate change impacts, the willingness to install RWHS isn't strongly correlated with these concerns. The survey results, as well as response from the key players, reveal a weak positive correlation between the perception of water scarcity as a pressing issue and the significance of the perceived impacts of climate change to their willingness to install RWHS, suggesting that those experiencing the effects of water scarcity and climate change might be less inclined towards RWHS.

Furthermore, a factor analysis reveals significant differences in how respondents rank factors influencing RWHS adoption, with cost and ease of installation, financial benefits, and environmental concerns emerging as top priorities. However, technical complexities and space requirements are perceived as barriers. Research by Ghofrani et al. (2013) shows that potential financial benefits, such as reduced water bills and savings on irrigation costs, are significant motivators for RWHS adoption, aligning with the study's finding of financial benefits as a top priority for some respondents, and Imteaz et al. (2014) identified technical complexities and lack of space as common barriers to RWHS adoption in developing countries.

These findings emphasize the need for a multifaceted approach to promote RWHS in Koronadal City. While raising awareness about perceived water scarcity and the adverse effects of climate change is important, it's not enough to drive widespread adoption. Addressing financial barriers through government support, simplifying system design and installation, and building trust through transparency and community engagement are essential strategies. Campisano et al. (2017) demonstrate the importance of tailoring RWHS design to local climate and urban conditions, as suggested in the result of this study utilizing the City of Koronadal's specific location, rainfall pattern, and urban design.

The study's limitations, such as the small sample size and potential biases in reported data, call for further research with a larger and more diverse sample. Additionally, investigating the reasons behind the weak positive correlation between water scarcity, the significance of perceived impacts of climate change, and respondents' willingness to install could provide valuable insights for targeted interventions.

This research provides valuable insights into the factors influencing RWHS adoption in Koronadal City. The results suggest that a comprehensive approach addressing financial, technical, and institutional barriers is crucial for promoting widespread adoption and ensuring sustainable water management in the city.

4.0 Conclusion

4.1 The Multi-Level Perspective and Sustainability Transition

One of the purposes of this paper is to examine how crises and niche innovations can lead to systematic change. Since transition management is a multilevel model of governance that shapes processes of co-evolution using visions, transition experiments, and cycles of learning and adaptation, this research could help policy-makers and society, in general, to transform themselves in a gradual, spontaneous way through guided processes of variation and selection, for further change towards sustainability transition (Rotmans, 2003). Transition management has rapidly emerged in developed countries as a new approach to dealing with complex societal problems and governance in the context of these problems. In the Netherlands, UK, and Belgium for example, serious efforts have been and are being undertaken to develop transition policies in areas such as energy, building, mobility, and water management as the result of a much broader scientific development of transition research as an interdisciplinary field of study in which innovation studies, history, ecology, and modeling are combined with sociology, political and governance studies and even psychology. Because of the focus on integrated sustainability problems and the applied nature of transition research, the natural interaction between science and policy has led to a continuous co-evolving theory and practice of transition management. (Loorbach et.al. 2006). Figures 4 and 5 below show the Multi-Level Perspective of RWHS Mainstreaming in Koronadal City's Setting relating to Geels' MLP Framework and Rotmans' Sustainability Transition Concept based on the examined socio-political and socio-technical contexts.

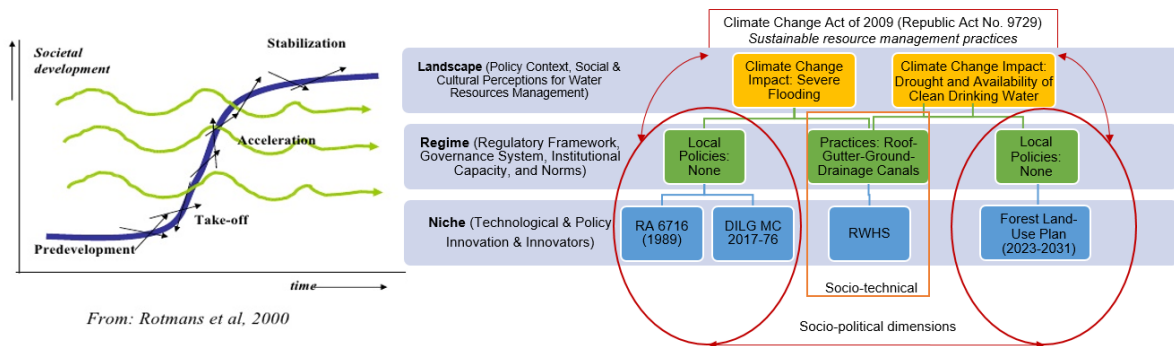


Figure 5. Multi-Level Perspective of RWHS Mainstreaming in Koronadal City's Setting relating to Geels' MLP Framework

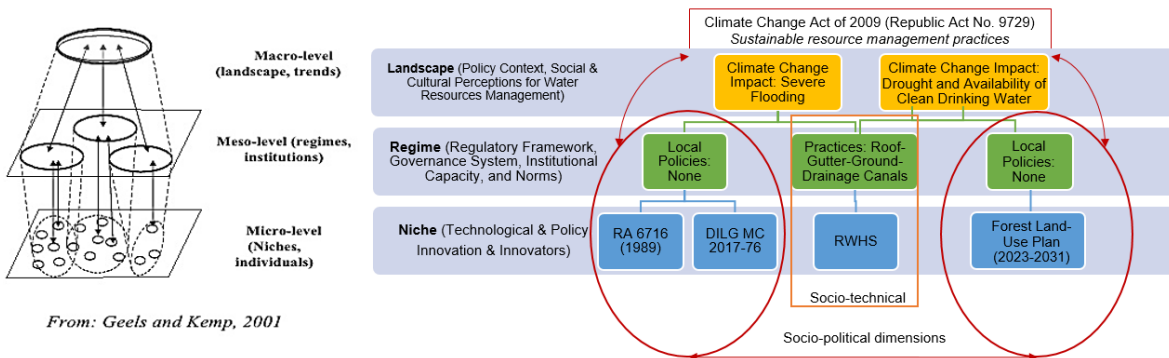


Figure 6. Multi-Level Perspective of RWHS Mainstreaming in Koronadal City's Setting relating to Rotmans' Sustainability Transition Concept

In the context of the City of Koronadal, results of the survey in households living in subdivisions, institutional, commercial, and other multi-functional establishments as well as the result of the key informant interview with city officials show that pressures from the current landscapes of water scarcity and significance of the adverse effects of climate change are acknowledged, but are not enough to break the existing regime of not collecting rainwater but rather letting it go directly to the ground. Even the effort from the national level through the MCs and JMCs providing policies and guidelines to the LGUs on the construction of RWHS did not gain legitimation and break the existing practices. As this paper examines what hinders the mainstreaming of the RWHS, several factors were identified and discussed in the previous chapter.

Relating the results to Rotman's Sustainability Transition Concept, RWHS is a technological niche that has been pre-developed but not appreciated enough for it to take off, further accelerate, and stabilize as part of the existing regime and improve the current landscape even with the issuances of MCs and JMCs which in that case also can be considered as a socio-political niche.

One key informant highlighted that the pressures are not enough to transition to mainstreaming RWHS as a form of water resources management initiative, while the others acknowledged the need to mainstream yet have technical and economic boundaries in doing so.

4.2 Factors Influencing the Breakthrough of RWHS

Breakthroughs happen at all levels in the MLP, but it is the landscape or the niche that usually puts pressure on the existing regimes (Kemp, 2011). This paper investigated the key factors that can significantly influence the breakthrough and widespread adoption of RWHS. How environmental conditions, economic considerations, policy frameworks, social acceptance, and technological advancements can all play a crucial role in paving the way for a more sustainable water future and resilient economy through RWHS implementation were explored.

4.2.1 Social and Community Factors

Public awareness not just about the features of RWHS but also how it can improve the quality of life of the public while ensuring equitable access to RWHS benefits for all is essential for long-term sustainability. The analysis done in the previous chapter reveals a complex interplay of factors influencing the adoption of rainwater harvesting systems (RWHS) in Koronadal City. Despite the acknowledged environmental benefits of RWHS, cost emerges as the most influential factor in the decision-making process. This suggests a potential division between environmental awareness and financial considerations, highlighting the need for targeted interventions that address both aspects. In this case, among the possible support and interventions presented, free storage tanks from the government were mostly preferred by the respondents.

The landscape pressures of water scarcity and climate change are acknowledged, yet they are not sufficient to overcome the practical and financial barriers to RWHS adoption. A multi-faceted approach in the form of a policy mix that would address these barriers, promote awareness, and provide support and intervention is crucial to fostering a shift towards wider acceptance and implementation of RWHS in Koronadal City.

4.2.2 Technological Advancements

The optimization study of Rainwater Harvesting Systems (RWHS) in Koronadal City focused on specific technical factors: climate and rainfall patterns, roof area, and storage capacity. While water quality is a crucial aspect of RWHS, it was not included in this study as it focused on rainwater reuse for domestic and irrigation purposes, excluding potable use. However, the integration of a first flush system for initial filtration was considered to enhance water quality for non-potable applications. The findings of the optimization study revealed that for an average roof area of 64.4 square meters of a household, a 2 cubic meters capacity storage tank is the most efficient based on the 10-year rainfall data collected while sixty (60) cubic meters for the Public Market of the City of Koronadal.

The study examined local regulations and building codes relevant to RWHS installations in Koronadal City. Interviews with city officials (City Engineer and City Architect) revealed that no specific policies have been established beyond those outlined in the Philippine Green Building Code. This highlights a potential area for

future policy development and technology advancements to further promote and regulate RWHS implementation in the city.

Furthermore, the Technological Innovation System (TIS) framework could be explored for future study to analyze and understand socio-technical transitions, such as the adoption of rainwater harvesting systems (RWHS) in Koronadal City as a complementary tool to the MLP framework. The TIS framework focuses on the micro-level dynamics of innovation, examining the interactions between various actors (individuals, organizations, and institutions), the knowledge base, networks, and infrastructure that support the development and diffusion of a specific technology. In the case of RWHS, the TIS framework would analyze the roles of homeowners, businesses, government agencies, researchers, and manufacturers in promoting or hindering RWHS adoption. It would also consider the availability of technical knowledge, financial resources, and supportive infrastructure. (Markard, 2015).

4.2.3 Economic and Financial Considerations

The economic viability of Rainwater Harvesting Systems (RWHS) in Koronadal City is sensitive to various factors. While the use of surplus materials and lower-quality cement could potentially reduce initial costs, a comprehensive sensitivity analysis is crucial to assess the impact on the overall benefit-cost ratio (BCR). Adhering to the national standard discount rate of 10% ensures consistency and comparability with other projects.

The Life Cycle Cost (LCC) analysis reveals that polyethylene (PE) is the most cost-effective material for RWHS in the long run, despite concrete having a lower initial cost. This underscores the importance of considering long-term costs in decision-making.

The inclusion of additional benefits, such as savings from home gardening using collected rainwater, limited damages to flora and fauna caused by soil erosion and siltation, and the cost of damages to lives and properties caused by severe flooding and drought can further enhance the economic attractiveness of RWHS. However, it's important to also acknowledge the challenges in quantifying intangible benefits like reduced stress and improved quality of life due to decreased flooding. Emphasizing these diverse benefits, the appeal of RWHS extends beyond its economic value, fostering greater willingness from individuals and institutions to adopt and invest in sustainable water management solutions.

4.2.4 Environmental and Resource Scarcity

Rainwater Harvesting Systems (RWHS) can present a multitude of environmental advantages. It can lighten pressure on existing water resources, contributing to improved water quality and ecosystem conservation. By reducing reliance on municipal water supplies, RWHS can indirectly help maintain water tables and protect sensitive ecosystems like the Bolok Creek.

Also, RWHS offers a practical solution to address the city's primary concern of flooding during pronounced wet seasons, exacerbated by climate change. The current drainage system, despite expansion and dredging efforts, struggles to handle excessive stormwater, particularly in the economically vital city center, hence RWHS can play a crucial role in stormwater management by capturing excess rainwater thereby mitigating flooding risks and protecting economic activities. With these environmental benefits, RWHS presents a sustainable and environmentally beneficial approach to address Koronadal City's water-related challenges.

4.2.5 Policy and Regulatory Framework

The current policy landscape in Koronadal City lacks a specific framework for promoting rainwater harvesting systems (RWHS) as a strategy for water resource management and climate change adaptation. While a proposed ordinance addressing septic waste management indirectly touches upon rainwater collection, it primarily focuses on separating wastewater from rainwater rather than promoting RWHS for its various benefits. However, the potential of RWHS to mitigate flooding and alleviate pressure on the drainage system, particularly the Bolok Creek, has been recognized. This presents an opportunity to incorporate provisions for rainwater storage and controlled release into the proposed ordinance. This would not only address the existing policy gap but also provide a practical solution to the city's flooding problem, contributing to its overall resilience to climate change impacts.

On the landscape level, the 35 years old law for Rainwater Catchment needs to be amended and jive with the existing laws that could relate to sustainable resources management and fulfill the constitutional right of every Filipino for a healthy and balanced ecology enshrined in Article II, Section 16, of the Philippine Constitution which states that the State shall protect and advance the right of the people to a balanced and healthful ecology in accord with the rhythm and harmony of nature.

Considering also the DILG MC No. 2017-76, the Local Government Unit of the City of Koronadal, or any LGU that lacks a specific policy framework for RWHS adoption, can be susceptible to administrative, civil, and/or criminal penalties.

4.3 Current Efforts and Difficulties in Mainstreaming RWHS

Key informants in Koronadal City recognize the pressures from climate change, particularly regarding severe flooding and rising temperatures. However, the lack of a policy framework specifically addressing water resource management and climate change adaptation, including RWHS mainstreaming, has hindered its widespread adoption. The absence of a supportive local policy and regulatory framework for RWHS, in line with the DILG memorandum and joint circulars, contributes to several difficulties in mainstreaming the technology. Limited social perception, lack of technical capacity and coordination, resource constraints, and shifting priorities among key players due to administrative changes are among the barriers identified. These challenges fall into the categories of social factors, economic considerations, and technical and institutional challenges.

To overcome these hurdles, a comprehensive policy framework that specifically addresses RWHS adoption is crucial. This framework should raise awareness about the benefits of RWHS, provide technical guidance and support, and incentivize adoption through financial mechanisms.

4.4 Roadmap for Sustainability Transition of Koronadal City through RWHS Implementation

Rainwater harvesting is a time-tested practice with modern technological advancements and offers a decentralized and sustainable approach to water resource management (Domenech & Sauri, 2011). As mentioned in the previous chapters, capturing and utilizing rainwater can reduce pressure on municipal waters and mitigate the adverse impacts of flooding. Moreover, it presents an opportunity to promote community resilience and enhance environmental sustainability.

This roadmap outlines a strategic pathway for the City of Koronadal to transition towards a more sustainable water future through the widespread adoption of RWHS, somewhat considering a framework complimentary to the MLP- the Technological Innovation System (TIS) framework adopted from S. Jacobsson and A. Johnson, “The diffusion of renewable energy technology: an analytical framework and key issues for research” (2000).

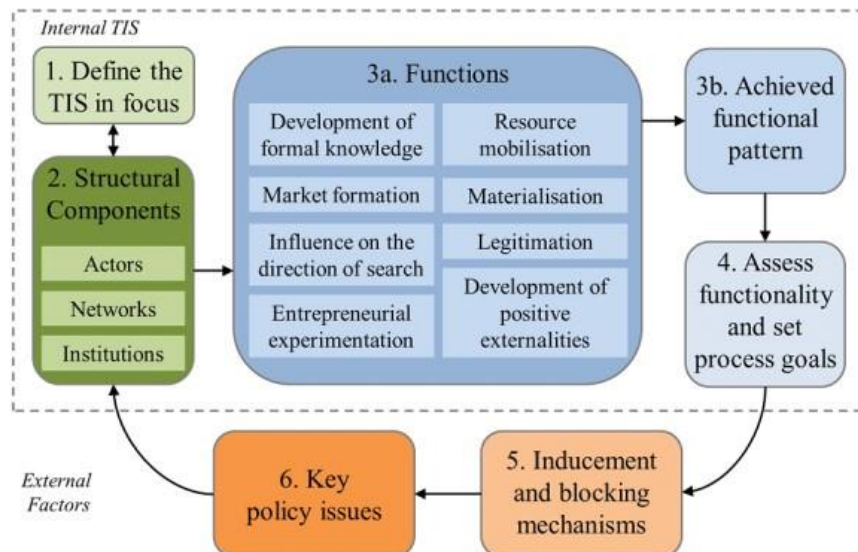


Figure 7. TIS framework adopted from Jacobsson, et.al., 2000

4.4.1 Phase 1: Awareness and Capacity Building (Year 1-2)

Launch comprehensive awareness campaigns targeting households, businesses, schools, and government institutions. Focus on the financial benefits of RWHS, such as reduced water bills and potential income generation through gardening and agriculture.

Conduct workshops, seminars, and training sessions for specific groups, such as homeowners, building professionals, and local government officials, focusing on the technical aspects of RWHS design, installation, maintenance, and water quality management (Ghofrani et al., 2013).

Campaign launching could utilize various media channels (radio, television, and social media) and community events to educate residents and businesses about the benefits of RWHS, its potential for flood mitigation, and its contribution to sustainable water management. (Ward et al., 2015)

Establish pilot RWHS projects in different settings (e.g., residential, commercial, institutional) to showcase the technology's effectiveness and address concerns about feasibility and maintenance. Encourage also the participation of private entities and non-government organizations in conducting campaigns, conducting feasibility studies, and even funding pilot sites.

4.4.2. Phase 2: Policy and Infrastructure Development (Year 3-5)

Develop and implement a comprehensive policy framework for RWHS, incorporating incentives, building code regulations, and water quality standards. This can be done through new local ordinances or by integrating RWHS into existing environmental and water management policies. (Domenech & Sauri, 2011)

Assess and upgrade existing drainage infrastructure to accommodate increased rainwater flow from RWHS and to mitigate flood risks, including expansion of drainage channels, improvement of retention ponds, and construction of green infrastructure. (Campisano et al., 2017)

Establish a network of trained professionals and technicians to provide support for RWHS installation, maintenance, and repairs involving partnerships with local businesses and educational institutions. (Senanayake et al., 2016)

Encourage design innovations from educational institutions, groups of inventors and designers, and technical professionals to come up with designs that are most viable in every unique setting.

4.4.3 Phase 3: Scaling Up and Mainstreaming (Year 6 onwards)

Explore the feasibility of making RWHS installation mandatory for new buildings or major renovations, particularly for large commercial and institutional structures as it can significantly increase RWHS adoption and contribute to city-wide water management goals. (Fewkes, 2006)

Encourage the formation of community-based organizations to promote and manage RWHS at the neighborhood or barangay level, and empower residents to ensure the long-term sustainability of RWHS initiatives. (Imteaz et al., 2014)

Implement a robust monitoring and evaluation system to track the performance and impact of RWHS across the city to provide valuable data for future policy adjustments and program improvements.

4.5 Summary

In Koronadal City's context of transitioning into a more sustainable water resources management and climate change adaptation for its constituents, the adoption of Rainwater Harvesting Systems (RWHS) faces challenges such as a lack of policy frameworks, limited awareness, financial constraints, and institutional barriers, despite the recognized potential of RWHS to address water scarcity and flooding. To overcome these challenges and promote RWHS adoption, a multifaceted approach is recommended.

The development of a comprehensive and integrated policy mix, combining regulatory measures, financial incentives, and informational strategies can create a supportive environment for RWHS adoption in Koronadal

City. Awareness campaigns and educational programs to inform various stakeholders about the benefits and functionality of RWHS can be targeted. Collaboration between relevant institutions and the developing technical expertise among professionals must be strengthened. Community engagement to build trust and to ensure the long-term sustainability of RWHS should also be prioritized. Securing long-term commitment by the key players in addressing social equity in RWHS implementation is also important. To attain a just transition towards a more sustainable society, policymakers must indulge in data-driven decision-making.

Summarizing and considering all the findings of this study, a policy recommendation in the form of a local ordinance with implementing rules and regulations is crafted for the area of study subject for their further studies and considerations.

5.0 Contributions of Authors

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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7.0 Conflict of Interests

All authors declare that they have no conflicts of interest.

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