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Abstract (for dissemination)	This deliverable provides BMP/I implementation guidance for the study areas (Egypt, Sudan, Ethiopia and Kenya). It begins by explaining the necessity of BMPs/Is, the goals of adding innovation into them, and how to choose them. Next, the study explains how to choose BMPs/Is and innovations and their possible benefits. The research also outlines BMPs/Is and innovation implementation in the study areas. Finally, the study suggests more research and action. These principles may help sustain the study locations and their ecosystems.
Keywords	BMPs, guideline, protocol

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Acronyms and Abbreviations

AICS Italian Agency for Development Cooperation

ASARECA Association for Strengthening Agricultural Research in Eastern and Central Africa, Uganda

AU-EU Africa-Europe

CIHEAM Centre International de Hautes Etudes Agronomiques Mediterranéennes, Italy

CNR Consiglio Nazionale delle Ricerche, Italy

DG DEVCO The Commission's Directorate-General for International Cooperation and Development

EU European Union

FAO Food and Agricultural Organization of the United Nations

HU Heliopolis University, Egypt

ISRIC International Soil Reference Center, The Netherland

KALRO Kenya Agricultural & Livestock Research Organization, Kenya

R&I Research and Innovation

WRC Water Research Centre, Sudan

STI Science, Technology and Innovation

SYKE Finnish Environment Institute, Finland

WATDEV Climate Smart WATer Management and Sustainable DEVelopment for Food and Agriculture in North and East Africa

WLRI Water and Land Resources Institute, Ethiopia

BMP(s)/I(s) Best Management Practice(s)/Innovation(s)

Executive Summary

This deliverable presents guidelines for the implementation of Best Management Practices and Innovations (BMPs/Is/Is) in the study areas (Egypt, Sudan, Ethiopia and Kenya). It begins by outlining the importance of BMPs/Is, the objectives of incorporating innovation into BMPs/Is, and the steps for determining the proper BMPs/Is to use. The paper then discusses the criteria for selecting the most suitable BMPs/Is and innovation, and the potential benefits of implementing them. Additionally, the paper provides a framework for the implementation of BMPs/Is and innovation in the study areas. Finally, the paper provides recommendations for further research and action. The guidelines presented herein have the potential to improve the sustainability of the study areas and help ensure the long-term health of their ecosystems.

1. Introduction

The need for BMPs/Is in agriculture in East Africa has been increasing over the years (Coulson and Ellman, 2018). This is mainly due to the ever-growing population and the need for more food production(Yamano, Otsuka and Place, 2014). The population growth is putting a strain on existing agricultural resources, and the need for more efficient and sustainable agricultural practices is essential. In order to meet the demands of a growing population, local farmers must embrace new management practices and technologies (Egziabher, 2014). This includes improved irrigation, mechanization, and pest control methods(Bluffstone and Köhlin, 2012). Additionally, access to data-driven decisions and precision agriculture can help farmers increase yields and optimize production. By embracing these technologies and practices, farmers can ensure that they are producing enough food to meet the needs of a growing population (Ammar, 2022).

There have been many efforts to develop BMPs/Is in East Africa, particularly Egypt, Sudan, Ethiopia and Kenya(Adar and Check, 2011; Okascha, 2013; Hamada, 2017; Ammar, 2022). This is due to the importance of agriculture in providing food, nutrition and income security to the local populations(Cowie, 2014; Negm, 2017; Samuel, 2020). Agricultural practices such as conservation tillage, crop rotation, and integrated pest management have improved yields and reduced the environmental impacts of farming(Kavanaugh, 2014; Samuel, 2020). In addition, advances in biotechnology, precision farming, and soil health have helped to improve crop yields and reduce input costs. These efforts are essential for the sustainable production of food, as well as for maintaining food security and economic growth(Adar and Check, 2011).

Many development projects failed to sustain their BMPs/Is benefits beyond the duration of the program implementing them(Yudelman, 1964; Quisumbing *et al.*, 2022; Yang, Dong and Shi, 2023). This is due to lack of knowledge and guidelines of the locals to effectively reproduce the procedure

BMPs/Is implementation(Yudelman, 1964; Ruthenberg, 1966). This issue is caused by both decision makers and farmers not being aware of BMPs/Is associated protocols of implementation(Helleiner, 1968; Akaki, 2003). Decision makers are often not aware of the necessary steps to successfully implement BMPs/Is, while farmers may not have sufficient access to the necessary information and technical knowledge(Food and Agriculture Organization of the United Nations, 2021; Nakaya *et al.*, 2022). This lack of knowledge can lead to farmers using methods that are not suitable for their particular environment, leading to inefficient use of resources and poor yields.

Farmers are often the people most affected by the failure of BMPs/Is, as they can be left with large losses(Yudelman, 1985; Dilebo *et al.*, 2023). In order to successfully introduce BMPs/Is, decision makers and farmers must be properly informed and educated on the benefits of using these practices, as well as the proper techniques to implement them. In addition, farmers may need access to technical assistance and support in order to ensure that best management practices are implemented correctly and effectively. By addressing the lack of knowledge of BMPs/Is, decision makers and farmers can create a more sustainable and profitable agricultural system. Without appropriate guidance and support, the implementation of BMPs/Is can be difficult and unreliable.

The present deliverable, practically illustrate know-how implementation D1.2.1, origin of the results in D1.1.1 and D1.1.2 to serve as guideline for the locals to reproduce step by step the WATDEV development framework starting from the repository of BMPs/Is population to the feasibility study.

2. The WATDEV development framework

The project consists of three main parallel paths that are integral in moving BMPs/Is from the collection campaign to the feasibility study and modeling. The first path (Figure 1) consists of establishing a profile of the local communities that are subject to the introduction/enhancement of BMPs/Is. The second path involves the collection of data in order to create an inventory of BMPs/Is. This data is then used to develop a comprehensive understanding of the current condition of the study area and its resources. It comprises a feasibility study based on the collected data that will determine which BMPs/Is are feasible in the current environment and can be implemented (First path). Finally, the third path involves the development of a model that can be used to assess the impacts of various BMPs/Is and their associated costs. This modeling will help to determine the most cost-effective and environmentally friendly BMPs/Is that can be implemented to protect and preserve the area. This path is a one time task to be accomplished. By following these three paths, the project will provide a comprehensive approach to protecting and preserving the resilience of the environmental resources while enhancing productivity of the cropping systems.

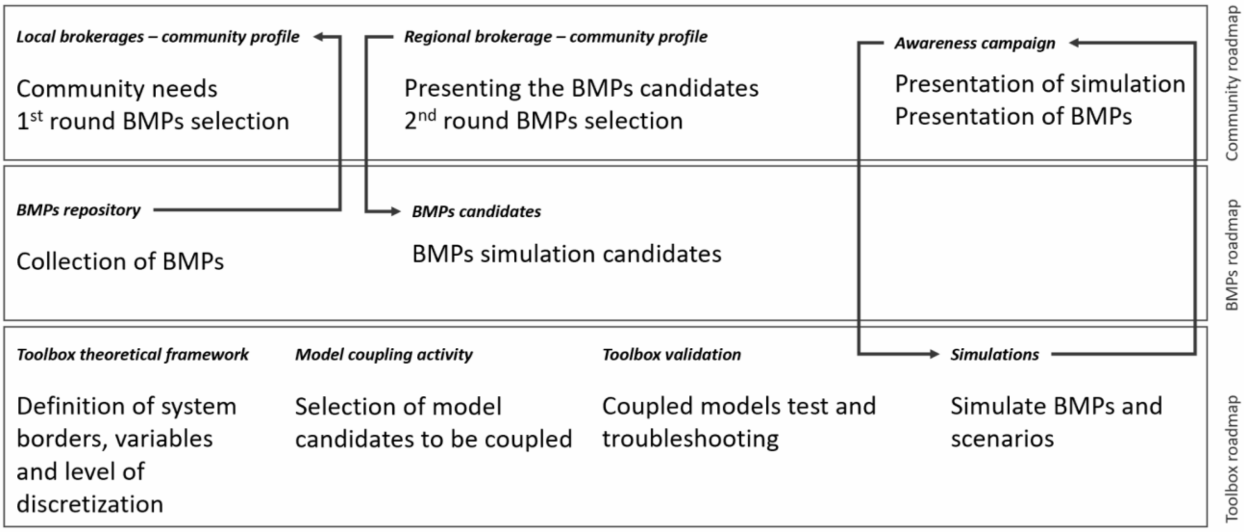

Figure 1 - The WATDEV development roadmaps and rational

3. Best Management Practices (BMPs)

BMPs are procedures and processes used to manage natural resources, such as water, soil, and air, in a responsible and sustainable manner. BMPs provide an effective and cost-efficient way to protect the environment from the impacts of human activities. They are used to reduce or eliminate environmental damage or pollution, conserve natural resources, and improve the quality of life of humans. BMPs are typically developed by government agencies, non-governmental organizations, and private companies among already existing/known practices for the locals and are tailored to the specific geographic and environmental conditions. The following sections provide a general overview of BMPs and the various types available.

3.1 Overview of BMPs

BMPs are a set of guidelines/technologies used to promote sustainable agricultural practices. They are designed to help farmers increase crop yields while minimizing the impact of their agricultural activities on the environment. BMPs can include changes in land use, such as crop rotation or cover crops, or changes in management, such as nutrient management plans. BMPs can also address other agricultural activities such as pesticide use, water conservation, and soil conservation. BMPs provide guidance on how to achieve environmental goals in an efficient and cost-effective manner. BMPs should be tailored to individual farms and their local environment to maximize their effectiveness.

3.2 Types of BMPs

Within the WATDEV context, BMPs are classified according to their sector of application within the SES (as described in D1.2.1, SES composition), as follow:

Table 1 - BMPs/Is typologies and associated example

BMPs sectors of application	Examples of BMPs/Is
Policy/law	Enforcement of practices by law regulation
Organization	Farm-to-Fork Partnership;Farmer-Led Extension Program;Local Food System Coordination;
Economical/financial	Farm Business Planning;Value-Added Production;Crop Insurance
Groundwater	Minimize fertilizer and pesticide;Use micro-irrigation;Soil infiltration structures
Surface water	Irrigation;Rainwater Harvesting;Reduced Tillage
Soil	Composting;Crop Rotation;Cover Cropping
Crop	Crop selection;Intercropping;Integrated pest management

3.3. Benefits of Implementing BMPs

BMPs are strategic for farmers to protect and enhance natural resources, such as soil, water, and air quality. BMPs can benefit local farmers in a variety of ways. First, implementing BMPs can help farmers save money by reducing costs associated with fertilizer, fuel, and pesticides. BMPs can also help protect soil health, reduce erosion, and improve water quality, reducing the need for costly inputs. Additionally, BMPs can help farmers increase their profits by improving crop yields and enhancing marketability. BMPs can also help farmers access new markets, as buyers increasingly demand products that are produced in an environmentally responsible way. Finally, BMPs can help farmers protect their land and communities for generations to come. By implementing BMPs, local farmers can reduce the impact of their operations on the environment, protecting their own land and the land of their neighbors. Implementing BMPs also helps farmers to develop a sense of pride and stewardship for their land, knowing that they are taking steps to conserve and protect it

4. Innovation in Practices

Innovations in BMPs are essential for the sustainable management of our agricultural resources. The challenges of climate change and population growth have placed an unprecedented strain on our agricultural systems and we need to be proactive in developing strategies to ensure their long-term viability. By utilizing the latest agricultural technologies, we can ensure that our farms are productive and efficient while still preserving the natural environment and minimizing our environmental impact.

Employing innovative technologies such as precision agriculture and digital agriculture can help us to increase yields, reduce inputs, and monitor environmental conditions and performance. Furthermore, innovation can help us to better understand the impacts of climate change and other environmental factors on our agricultural systems. By investing in research and development, we can develop more resilient crops and farming practices that can withstand extreme weather events and other impacts of climate change.

4.1. Overview of Innovation in BMPs

Recent innovations in agricultural BMPs have focused on improving the efficiency of crop production, utilizing precision agriculture and precision irrigation, reducing water usage, and utilizing cover crops and other soil health practices.

Precision agriculture refers to the use of technology to measure and monitor crop health, soil nutrients, and water usage on a field-by-field basis. Through this technology, agricultural producers can adjust their management practices to optimize crop yields and reduce inputs.

Precision irrigation is the use of technology to measure and monitor soil moisture levels on a field-by-field basis. Through this technology, producers can adjust their irrigation practices to reduce water usage and improve crop yields.

Cover crops are non-cash crops that are planted in between cash crops to improve soil health, reduce erosion, and improve water infiltration. Cover crops also improve soil fertility and reduce compaction.

Other soil health practices include no-till farming, crop rotation, and the use of compost and other organic amendments. These practices improve soil structure, reduce erosion, improve water infiltration, and increase soil fertility.

In addition to these innovations, there have also been advances in the use of integrated pest management, which is the use of natural pest predators, insecticides, and other techniques to reduce the need for chemical pesticides. This reduces the amount of pesticide runoff and improves the health of the environment.

Overall, recent innovations in agricultural BMPs have focused on improving the efficiency of crop production, reducing water usage, and improving soil health. These innovations have the potential to improve crop yields, reduce input costs, and benefit the environment.

4.2. Types of Innovations

Innovations helped farmers to reduce the amount of pollutants entering into water sources, thereby improving water quality. Technologies such as precision agriculture, remote sensing, and geographic information systems (GIS) supported farmers to better understand their environment, identify potential sources of pollution, and manage land and water resources more effectively. Additionally, technologies such as nutrient management and irrigation scheduling greatly enhanced cropping to receive the right amount of water, nutrients, and other inputs at the right time, resulting in better yields and improved environmental outcomes.

Advancement and innovations can be sorted as follow:

1. Financial Management Practices: Risk management and cost-saving measures.
2. Precision Agriculture: Precision agriculture is an agricultural technology that uses advanced monitoring and sensing devices to measure and adjust inputs such as water, fertilizers, and herbicides in order to optimize crop yields. The technology helps farmers make decisions based on real-time data, such as soil conditions, weather, pest populations, and crop health.
3. Remote Sensing: Remote sensing is a technology that uses satellites, aircraft, or drones to capture data about a field or region. This data is then used to develop detailed maps of the land and its characteristics, such as soil types, crop health, and water resources.
4. Crop Sensors: Crop sensors are devices that measure environmental factors such as temperature, sunlight, soil moisture, and nutrient levels. This information helps farmers make decisions about when to irrigate, fertilize, and apply pesticides.
5. Variable Rate Fertilization: Variable rate fertilization is a technology that uses precision agriculture to apply different amounts of fertilizer to different areas of a field, depending on the soil type and other factors. This helps farmers reduce their fertilizer use and save money.
6. Irrigation Technology: Irrigation technology includes systems such as drip irrigation, sprinkler systems, and micro-irrigation, which helps farmers reduce water usage and conserve water resources.
7. Greenhouse Technology: Greenhouse technology is used to control the environment inside a greenhouse. This helps farmers better manage temperature, humidity, and other environmental factors to maximize crop yields.

4.3 Benefits of Implementing Innovations

Innovations in agriculture have many benefits over traditional methods. Modern practices allowed farmers to maximize the productivity and efficiency of their operations, while minimizing their environmental impact. They also make it easier for farmers to respond to changing market conditions and consumer preferences.

High-yielding crop varieties, improved irrigation systems, and increased use of fertilizer and pesticides permitted farmers to get more out of their land and resources. For example, precision agriculture techniques allow farmers to apply fertilizer, water, and other inputs in the exact amounts needed for each crop, leading to significant savings in inputs and improved yields.

In addition, modern management practices are often more sustainable than traditional methods. Farmers can use cover crops, crop rotation, and other sustainable practices to improve soil fertility, conserve water, and reduce erosion. These practices can also benefit farmers financially by reducing costs and increasing yields.

Finally, modern management practices are often more cost-effective than traditional methods. For example, using modern technology such as sensors, data analysis, and remote sensing can help farmers identify areas of their farms that need attention, leading to more efficient use of resources and improved yields.

Overall, modern management practices in agriculture can provide many benefits over traditional methods, including higher yields, improved sustainability, and cost saving.

5. Process for Implementing BMPs/Is and Innovations: The WATDEV Approach

This section provides a comprehensive overview of the conceptual framework illustrated in Figure 1, which is the foundation of the WATDEV project. Through this framework, we will explore the various components of the project, their objectives, and the strategies necessary to implement them.It is worth mention that the framework was implemented protocoligorically for the 4 countries study areas (i.e. Egypt, Sudan, Ethiopia and Kenya).

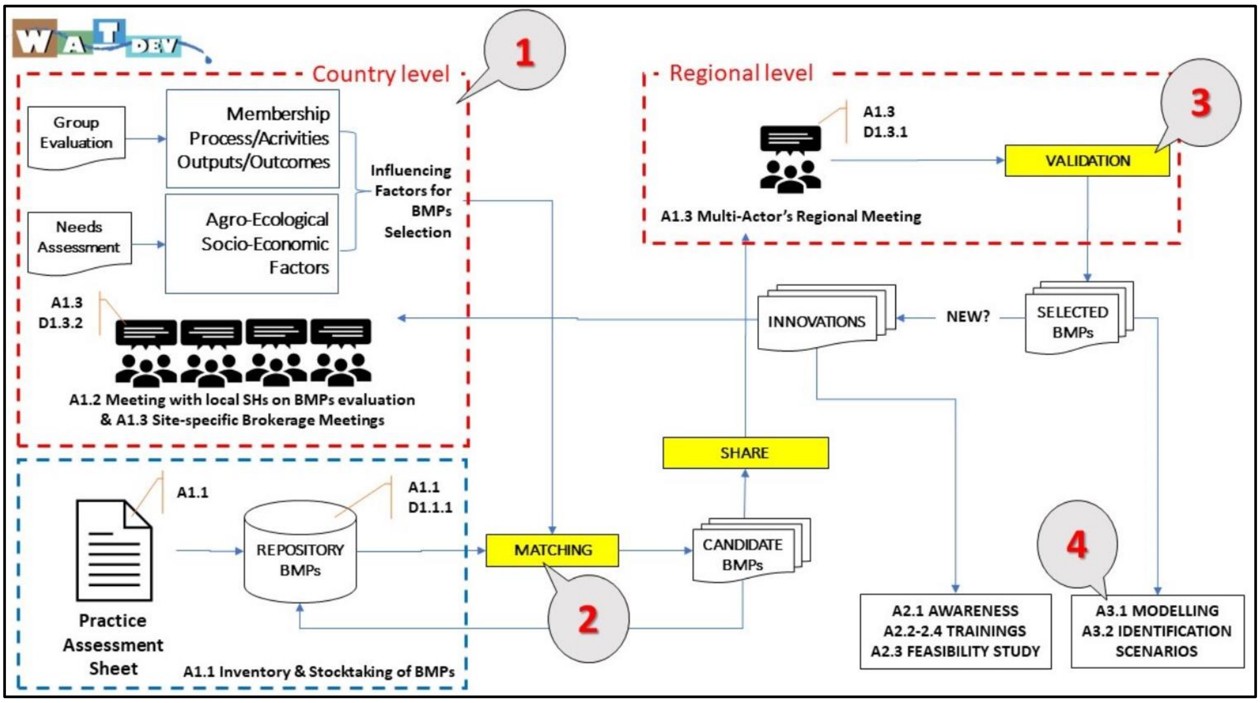

Figure 2 - The WATDEV development framework

5.1. The Community Roadmap

Studying the community before a project implementation has a purpose to gain an understanding of the existing community dynamics, their needs and priorities, the resources available to them, and the potential for success with the project. It will also help to identify any potential challenges or opportunities for the project in terms of the local environment and cultural acceptance. This information can be used to design the project in a way that is more likely to be successful in meeting the needs of the community and achieving the desired outcomes.

5.1.1 Local Brokerage

The goal of a community needs assessment is to provide BMPs/Is that will improve the sustainability and productivity of cropping systems. A community needs assessment looks at the current state of the agricultural system in the area of interest and examines the needs of the involved community, such as the types of crops being grown and the type of farming practices being used. The assessment results are used to select BMPs/Is that are tailored to the local environment to ensure optimum fit.

5.1.2 Regional Brokerage

Regional brokering is important because it helps to ensure that the project is successful on a larger scale. Local brokering involves identifying local stakeholders and engaging them in the project. Regional brokering, on the other hand, helps to build capacity and expand the project's reach through a larger network of stakeholders, resources, and information. This helps to create more sustainable agricultural systems that are better able to adapt to local, regional, and global changes. Regional brokering also helps to strengthen relationships between local stakeholders, enabling them to learn from each other and share resources and knowledge. Finally, regional brokering helps to provide BMPs/Is that best suite country level development strategies with highest funding opportunity.

5.1.3 Awareness Campaign

Awareness, capacity building and training are essential components in any agriculture development project. Awareness-raising activities are needed to inform farmers about the potential of agricultural development, such as new methods and technologies, and to ensure that the BMPs/Is objectives are properly understood in the local context. Capacity building is necessary to ensure that the BMPs/Is are well-managed, that the resources are used efficiently, and that the BMPs/Is intended outputs are achieved. Training is essential to ensure that the farmers are able to use new technologies effectively. Training should also be provided on the most appropriate use of BMPs/Is associated materials (i.e. models, software, toolbox). All of these components are necessary to ensure that the BMP/I is successful, and that the farmers are able to benefit from its implementation.

5.2. The BMPs/Is Roadmap

Building up a repository of BMPs/Is comprises two major steps, a survey and selection. The survey has no geographic and/or contextual limitation, whereas the selection is a filtering of the collected repository to fit best the local areas of study. The detailed process is as follow:

5.2.1 BMPs Repository

Data for BMPs/Is are gathered from a variety of sources. These include published research, government agencies, agricultural organizations and project partners. A database to store the collected BMPs/Is. Create, depending on the type of BMP/I (target application), a database to store and sort the BMPs/Is.

Develop a process for updating the database. This could involve regularly checking for new BMPs or allowing users to submit their own BMPs.We advice to create an interface for users to access/update the database. This can be a website, mobile app, or other user-friendly interface.

Test the repository for both data consistency and integration to the modeling tool (i.e. toolbox).

5.2.2 BMPs Candidates

The environmental sustainability check aims to evaluate the viability of each candidate BMP/I while taking into consideration the local context. This includes considering potential ecological, social and economic impacts of the BMP/I. The assessment also takes into account the cost-effectiveness of the proposed solutions. Following the assessment, a report is generated outlining the potential BMP/Is that can be adopted by the community. The report also provides recommendations for the implementation of the BMP/Is to ensure environmental sustainability. The final decision for adoption rests with the community, who can choose to accept or reject the proposed solutions.

5.3. The Toolbox Roadmap

Model coupling is a powerful tool for simulating complex systems. It allows to study the behavior of a agrohydrologic systems in a more accurate and detailed way than traditional models. With the right combination of models and data transfer protocols, model coupling can be used to simulate a wide variety of system variables and provide valuable insights into their behavior.

5.3.1 Toolbox Theoretical Framework

The Toolbox development is based on model coupling. It is the process of connecting two or more computer models to create a single, more powerful model. It is used to simulate complex systems, such as agrohydrologic one, in which the effects of multiple factors must be taken into consideration. The goal of model coupling is to create a model that accurately captures the behavior of the system being modeled, while also providing a platform for further research and development.

Nevertheless, spatial, temporal and scale boundaries need to be defined. Indeed, these boundaries should be based on the specific research questions and hypotheses being tested, as well as the available data and resources. For example, a study of air pollution may need to focus on a certain geographic region or time period, while a study of water quality may need to focus on a specific geographic area or a certain time frame. Additionally, the scale of the study should be determined, such as whether to focus on a local, regional, or global scale.

5.3.2 Model Coupling

Model coupling involves several steps. First, the existing models must be identified and chosen. The models should be chosen based on the type of system being modeled and the specific goals of the project. The models should be compatible with each other, and each model should have the necessary inputs and outputs for the coupling process.

Second, the models must be connected. This step involves creating an interface between the models so that data can be exchanged between them. This involves writing software to allow the models to communicate, or creating a common data format that can be used to share data between the models.

Third, the data transfer protocols must be established. This involves deciding how data will be exchanged between the models, and what type of data will be used. This can involve establishing the type of data to be sent (e.g., integers, floats, strings, etc.), the format of the data, and the frequency of the data transfer.

5.3.3 Toolbox Validation

Validation consists of running the coupled models and comparing the results to the results achieved when the models were run separately. If any discrepancies are noted, adjustments should be made to the models or the data transfer protocols.

5.3.4 Simulations

The coupled models should be used to investigate the system being modeled. It involves running simulations to study the behavior of the system with different BMPs/Is. This allows us to evaluate the effectiveness of different strategies and identify the most effective solutions for a given system. Additionally, the coupled models can be used to forecast future scenarios given different input parameters, such as climate change and land use changes. This is important for decision-makers and stakeholders to understand the potential impacts of their decisions, and model solutions that will have the greatest benefit for their particular case.

6. Monitoring and Evaluation of BMPs/Is and Innovations

Monitoring and evaluation of BMPs/Is are essential tools used to assess the effectiveness of programs and projects. It is important to have an effective monitoring and evaluation system in place to ensure that the objectives of the programs and projects are achieved.

6.1 Benefits of Monitoring and Evaluation

Monitoring and evaluation of BMPs/Is can provide many benefits to the stakeholders involved. First, it can help to ensure that the BMPs/Is are meeting the desired goals. Monitoring and evaluation can also help to identify any problems with the BMPs/Is or innovations and allow for corrective action to be taken. Additionally, monitoring and evaluation can provide information that can help inform decision-making regarding future BMPs/Is. Finally, monitoring and evaluation can also help to generate data that can be used to evaluate policy effectiveness and help provide guidance on future policy.

6.2 Process for Monitoring and Evaluation

The process for monitoring and evaluating BMPs/Is should include the following steps:

1. Establish measurable goals and objectives: The goals and objectives should be established through collaboration between the organization, the stakeholders, and other experts. The goals should be SMART (specific, measurable, achievable, realistic, and time-bound).
2. Collect baseline data: The baseline data should be collected to provide a comparison for monitoring and evaluating the effectiveness of the BMPs/Is.
3. Develop a monitoring and evaluation plan: The monitoring and evaluation plan should outline the methods, frequency, and duration of data collection, as well as the criteria for evaluating the effectiveness of the BMPs/Is.
4. Implement the monitoring and evaluation plan: The monitoring and evaluation plan should be implemented according to the timeline and procedures outlined in the plan.
5. Analyze and interpret the data: The data should be analyzed and interpreted to determine the effectiveness of the BMPs/Is.
6. Make recommendations for improvement: Based on the analysis and interpretation of the data, recommendations for improving the BMPs/Is have to be made.
7. Develop an action plan: An action plan should be developed to address any issues identified through the monitoring and evaluation process.
8. Monitor progress and adjust the action plan: The progress of the action plan should be monitored and adjusted as needed to ensure that the BMPs/Is results are achieved.

7. Conclusion

By applying the present protocol for implementing BMPs/Is, the following goals could be achieved for all the WATDEV study areas, regardless of their socio-economic and/or environmental differences:

- Establish a framework for BMPs/Is implementation that is based on local needs, priorities, and resources.
- Develop local partnerships between government agencies, non-governmental organizations, and local stakeholders to ensure that BMPs/Is are implemented appropriately and effectively.
- Develop a monitoring and evaluation system to track the progress of BMPs/Is implementation, and to identify potential areas for improvement.
- Encourage stakeholder participation in the development and implementation of BMPs/Is.
- Provide resources and incentives for local stakeholders to adopt and implement BMPs/Is.
- Develop an integrated approach to BMPs/Is implementation, including the use of multiple strategies and tools.
- Support research and development of innovative technologies and practices to address local needs.
- Develop communication strategies to ensure that information about BMPs/Is is widely disseminated.

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