Vietnam Journal of Science and Technology ***61*** *(2) (2023) 268-281*

doi:10.15625/2525-2518/16432

Developing solutions roadmaps for rice production in flooding area of the Vietnamese Mekong Delta adapting to uncertain changes in climate and surface water resources

Hong Minh Hoang[1,*], Nguyen Hong Tin[1], Dinh Diep Anh Tuan[2], Van Pham Dang Tri[2]

[1]*Mekong Delta Development Research Institute, Can Tho University, Campus II, 3/2 Street, Ninh Kieu District, Can Tho City, Viet Nam*

[2]*Research Institute for Climate Change, Can Tho University, Campus II, 3/2 Street, Ninh Kieu District, Can Tho City, Viet Nam*

[*]Email: *hmhoang69@gmail.com*

Received: 19 August 2021; Accepted for publication: 21 October 2021

Abstract. Climate change, hydropower dams, and socio-economic development in the Mekong River areas have resulted in unpredictable changes in surface water resources and agricultural practices in the Vietnamese Mekong Delta (VMD), the decisions making on water resource management challenging in the region. This study aims at applying the Dynamic Adaptive Policy Pathways (DAPP) approach to develop solutions roadmaps supporting rice production in the Mekong Delta with a projection to 2030 under the context of uncertain changes on surface water resources. Data were collected from local officers, farmers, experts at Can Tho University, TU Delft University, and Utrecht University via using semi-structured interview techniques including stakeholder workshops, group discussions, and in-depth interviews. The proposed solutions from stakeholder's opinions were evaluated at different socioeconomic and environmental dimensions, especially focusing on the time of executing the tipping point of each solution. The study presents two solutions roadmaps developed as examples to promote rice production in flooding area of the VMD, which are validated and consolidated by the participated stakeholders. The DAPP approach could be suitable to support decision-making on surface water resources management in the context of uncertain changes, it is helpful reference for policy makers on agricultural land and water use planning. And Further studies should be developed to apply this approach to other regions in the VMD to reinforce the applicability of the DAPP approach on supporting decision-making in the context of increasingly uncertain changes in the VMD.

Keywords: decision-making approach, uncertain changes, water resources management, Vietnamese Mekong Delta.

Classification numbers: 3.5.1, 3.5.2.

1. INTRODUCTION

Water resources continue to play an important role in socio-economic sustainable development of nation; however, its quality and quantity are decreasing while the demands for water are increasing. Water resource changes are driven by a variety of variables and this process is fluctuated overtime. Therefore, water resource management issues should be evaluated from a variety of perspectives, unfortunately, studies on analysis and evaluation of those are limited, particularly in developing countries, due to a lack of facilities and approaches to assist in decision-making [1]. It is difficult to make an effective choice on water resource management in the future due to unanticipated changes in climate, socio-economic development, and policy relating to water resources [2]. Currently, decision-making is frequently based on predicted scenarios that do not cover all possible factors, this results in applying solutions is ineffective, especially in the case the future environment differs from the initial development plan [3, 4]. In principle, developing, drafting, and executing any plan is a time-consuming and expensive process, so in the case developed plans differ from actual expectations, it causes significant losses of resources including time and finance, as well as negative impacts on common growth [3]. Furthermore, problems relating to water resource fluctuation are usually nonlinear and seem to be complicated systems in which decision-makers frequently restrict general understanding about concerns relating to water resource variation. It brings difficulties for decision-makers in selecting the best solution for water resource management [4]. As a result, instead of relying on simulation findings, the current approach to water resources management should focus on risk management in order to react to the uncertainties. Distinct strategies and approaches enabling decision-making have been investigated and utilized depending on the characteristics of different spatial, temporal, and objective contexts. Typical approaches on water resource management have been used, such as the Dynamic system approach [5 - 7], Real options analysis – ROA [8 - 10], Robust decision making – RDM [11 - 13], Adaptation pathways -AP [4, 14, 15], Adaptive policy-making – APM [16, 17], and Dynamic adaptive policy pathways – DAPP [16,17]. In the mentioned approaches, the DAPP approach is evaluated to be effective in supporting decision-making in adaptive water resources management with future uncertainty [10, 11, 18]. The theory of the DAPP framework is concretely guided by the implementation process and mathematical modeling tool aid in the selection of optimal solutions [19]. Even though the DAPP approach was applied in integrated water resources management in the world, it still has limitations for applying practical context in Viet Nam. Therefore, this study applied the DAPP approach to develop solutions roadmaps for rice development in the VMD’s floodplain to adapt to uncertainty of climate change impacts and surface water resources availability change in the Mekong River.

The Vietnamese Mekong Delta (VMD) is one of the global deltas negatively affected by climate change and hydropower development in the Mekong River. Approximately 80 % of the surface water resources in the VMD come from outside of the territory. Therefore, any changes in discharge to the Mekong River will have a significant impact upon the surface water resources of the VMD [20, 21]. Changing surface water resources in the VMD has been linked to increased erosion [22], changes in river morphology [23], changes in flood water levels [24], and reduced sediment accumulation [25]. In addition, internal socio-economic and agricultural growth, such as rice intensification and changes in land-use patterns, also had impacts upon the VMD's surface water resources [21, 26, 27]. These characteristics are interrelated and they include uncertainties that make managing surface water resources in the Delta to be problematic in the present and future. Meanwhile, the surface water resources management in the VMD has many limitations, such as overlap in functions and tasks among agencies, and decision-making in water resources management has not taken into account future uncertainties [28, 29]. To adjust to the uncertainties and ensure water sources for sustainable agriculture development in the VMD, there should be changes in the decision-making method on surface water resource management. Therefore, this study aims to apply the DAPP approach to develop solutions roadmaps in surface water resource management for rice production in the Delta's floodplains in order to adapt to climate and surface water resource changes in the Mekong River.

2. METHODOLOGY

2.1. Study framework

The study framework (Figure 1) was developed based on the theory of integrated water resources management (IWRM) to describe different factors impacting on water resource management and agricultural production under uncertainty contexts in flooding areas of the VMD. The factors shown in the study framework include:

- External factors: include changes of surface water resource availability from the Mekong River and climate change. In particular, the impacts of climate change were integrated into the evaluation process such as rainfall, temperature, and extreme weather that directly impact on agricultural production in the study area.
- Agricultural factors: include farming patterns, soil and water quality for farming activities, and market fluctuation.
- Irrigation system factors: include dikes, sluices gates, pump-station and canals system.
- Management factors: include implementation of policies, plans, solutions in agriculture development, and the monitoring and evaluation impacts of factors on water surface resources and agricultural production in the study area.

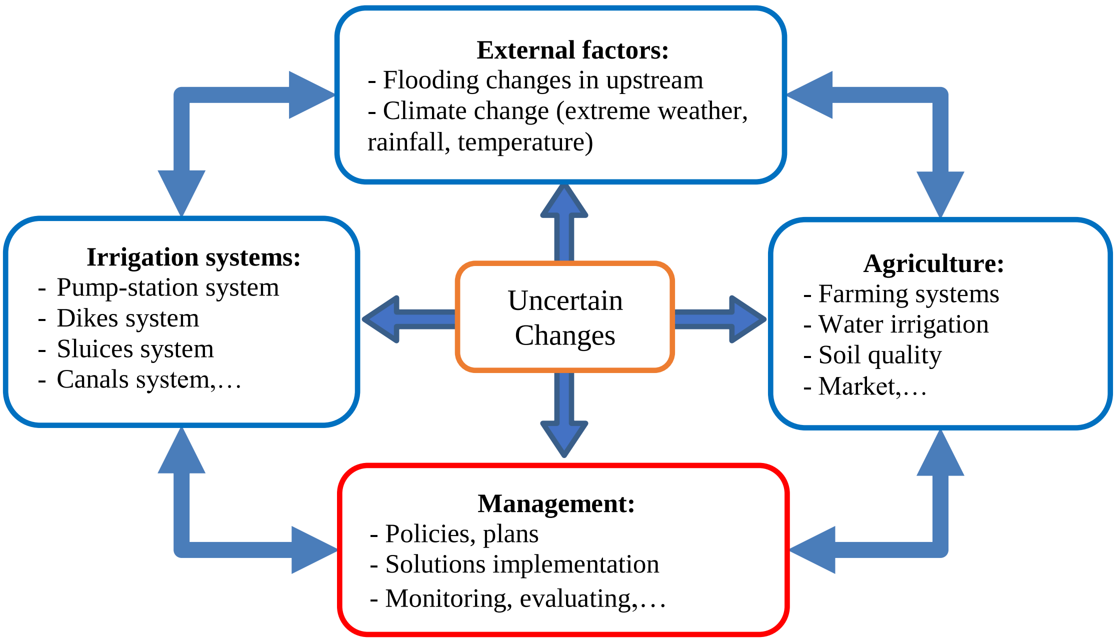

Figure 1. The study framework.

There is an interaction between surface water resources and agricultural production in flooding area of the VMD, and both are currently affected by surface water resources changes in the Mekong River and climate change. These impacts are increasingly following the unpredictable trend and creating many uncertainties that lead to the high pressure on management in both adaptation and meet future agricultural development goals in the study area. Currently, the management of water resources and agricultural production in the study area still has many limitations, especially there is an isolation and inconsistency in the solutions implementation that makes it difficult to achieve the goals of planning development. This study focuses on the current problem of limitations in solutions implementation by applying a new approach in building solutions roadmaps for rice production development in the study area to 2030 in the context of uncertain changes in surface water resources in the Mekong River and climate change.

2.2. Study area

The study selected sub-region I.1 (Figure 2) in zoning irrigation planning of Dong Thap province (Viet Nam) to 2050 [32], representing flooding area in the VMD, to develop solutions roadmaps for rice production to adapt to the changing climate and surface water resources. The study area is directly affected by flood in Tien River during the whole year and overbank flows (from the common border between Viet Nam and Cambodia) during the annual flooding season. The main existing land use types in the study area are double and triple rice systems. The current constructed irrigation systems have multi-functions like water management (supply and drainage), preventing floods, and transportation. In the double rice area, the irrigation systems are August dyke systems (low and temporary/uncompleted) that are usually facing the impacts of erosion and inundation.

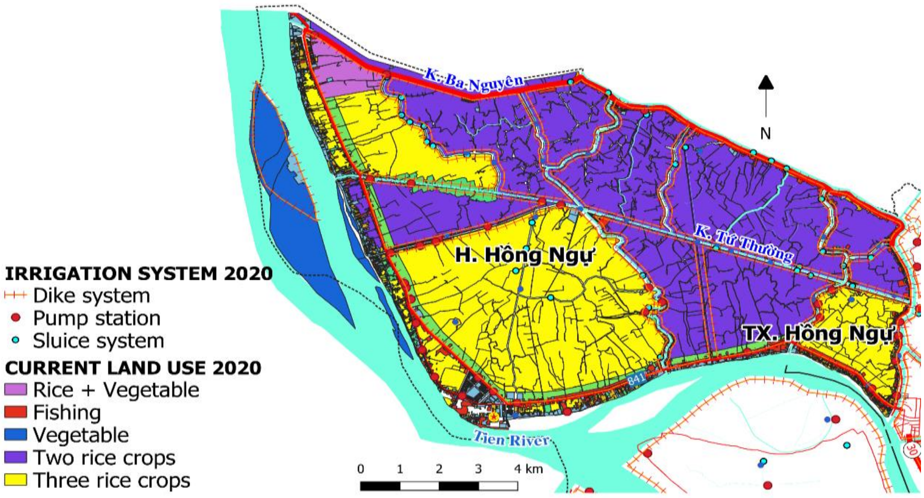

Figure 2. Land use in 2020 of the study area.

2.3. Data collection

2.3.1 Stakeholder workshop

A workshop at the Can Tho University was organized to discuss the issues related to surface water resources management, rice production, and climate change in the VMD, focusing on the study area. In addition, in the workshop, the participants also offered, analyzed, and selected suitable solutions for rice production in the study area. The participants were the scientific experts on climate change, water resources management, farming systems, and socio-economic fields at Can Tho University, TU Delft University, and Utrecht University.

2.3.2 Key person interview

The officers at the provincial, district, and commune levels were invited to interviewed in the current status of rice cultivation and changing in surface water in Dong Thap province. At the provincial level, the study interviewed representatives from the Department of Natural Resources and Environment (DONRE), and Department of Agriculture and Rural Development (DARD). At district level, the study interviewed representatives of the Division of Agriculture and Rural Development in all the districts of Dong Thap province. At the commune level, the study interviewed commune staff in charge of agriculture management of three communes in the study area.

2.3.3 Group discussion

Six group discussions were organized to collect data relating to rice cultivation including technology, trading, impacts of climate change, and surface water resources changes. Among discussions, 03 groups of double rice systems, and 03 groups of triple rice systems, each group included 8-10 participants.

2.3.4 Farmer interview

In this study, 180 rice farmers were interviewed to collect data on livelihood capital and activities, impacts of changes in surface water resources on rice production at farm level. In addition, farmers' further livelihood strategies and conditions to operate those strategies are also involved.

2.4. Building solutions roadmaps

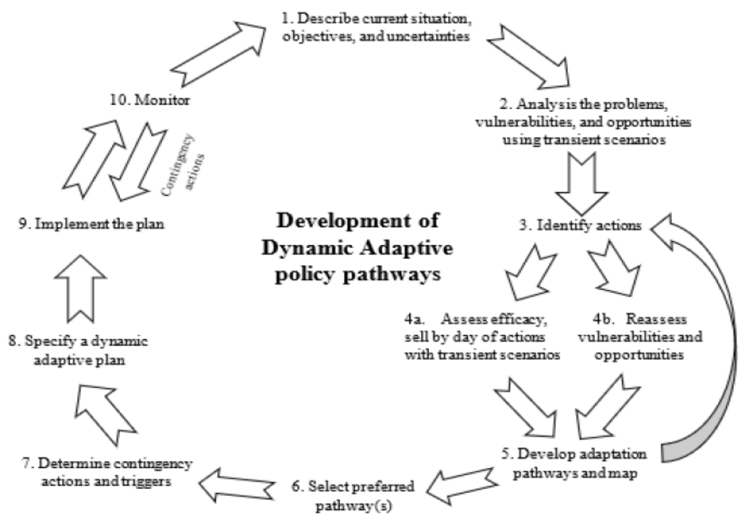

Figure 3. The dynamic adaptive policy pathway approach on water resources management [30].

The DAPP decision-making approach was applied to develop solutions roadmaps on surface water resource management for rice production to 2030 in flooding area of the VMD. The DAPP approach (Figure 3) includes 10 steps, in which the study focuses on steps 1 to 7 to develop solutions roadmaps.

Step 1: The study conducted field surveys to collect data on farming activities, irrigation systems, and future production development plans, with a focus on rice production. In addition, the study investigated the impact of changes in water resources in the Mekong River and climate change on water resources management for rice production via group discussions.

Step 2: The study applied the system analysis framework DPSIR (Driver forces, Pressures, Status, Impacts, Responses) and sustainable livelihood development framework DFID to analyze and evaluate the current status of rice production in the study area under the impact of climate change and changes in water resources in the Mekong River based on the collected data in Step 1. This step identifies the benefits, drawbacks, and highlight critical issues, particularly the uncertain changes that may affect rice production development objectives in the study area to 2030. In addition, the study synthesizes solutions that can meet the goal of rice production development in the study area to 2030, including solutions to enhance local advantages and solutions to adapt to uncertain changes in the future.

Step 3: The study organized an expert workshop at Can Tho University to discuss and analyze solutions to be implemented for the goal of developing rice production in the study area until 2030. In the workshop, the study presents the results in Step 1 and Step 2, including advantages and disadvantages in the current situation, challenges and uncertain changes in the future, and solutions for implementation. The result of the workshop was to determine the solutions implementation that were proposed in Step 2 to support the objectives of rice production in the study area to 2030. The solutions were considered in multi-criteria evaluation (Table 1) and quantification based on the Likert scale of 5-level including represented positive and negative effects by participants in the solutions development process. The study proposed two groups of solutions implement, including (1) a group of solutions for irrigation and (2) a group of solutions for agriculture.

Table 1. The criteria for evaluating solutions.

No.	Criteria	Explanation
1	Implement ability	Does the solution solve the current problem and meet the future goals in implementation?
2	Human resources	Can the implementation capacity, in particular, the factors of local capital and human resources meet the implementation of the solution?
3	Socio-economic efficiency	Does the solution bring socio-economic effects (directly or indirectly) to the study area?
4	Impact on livelihoods	The implementation of the solution affects the livelihoods of farmers in general (increase, decrease, and remain constant) in the place where the solution is implemented as well as elsewhere, or impact in the future.
5	Impacts on surface water resources	The implemented solution has impacts (positive, negative) on the change of surface water resources (including quality and discharge) in the place of implementation as well as impacts elsewhere.

Steps 4: The study directly consulted with experts from Can Tho University, TU Delft University, Utrecht University, and representatives from Departments of Agriculture and Rural Development, Departments of Natural Resources and Environment and Divisions of Agriculture and Rural Development of all districts in Dong Thap province to evaluate the solutions selected in Step 3 and specify the tipping point (time for transfer) of solutions. The solutions were considered in multi-criteria evaluation (Table 1) and quantification based on the Likert scale of 5-level including represented positive and negative effects by participants in the solutions development process. The criteria given are based on Decree No. 01/2020/ND-CP and Decree No. 84/2015/ND-CP on monitoring and evaluation of investment projects.

Steps 5: The study synthesized the evaluation results of experts from Steps 4 and used the Pathway tool to design a map of solutions like shown in Figure 4. The solutions map shows the time span in the period of plan and the tipping point of the solutions. Besides, the solutions map also shows the transfer time between difficult solutions. The solutions map shows the performance characteristics of the solutions as well as the variety in the implementation of the solution. It can be explained that when a solution is implemented, it is only effective in a certain period of plan, meets all the stages of plan, and supports as a condition for another solution implement. Therefore, the solutions map is meaningful in showing the characteristics of solutions (implement time, transfer time, and ability to implement solutions) and serve as a basis for analysis and select solutions roadmaps for the development of rice production in the study area by 2030.

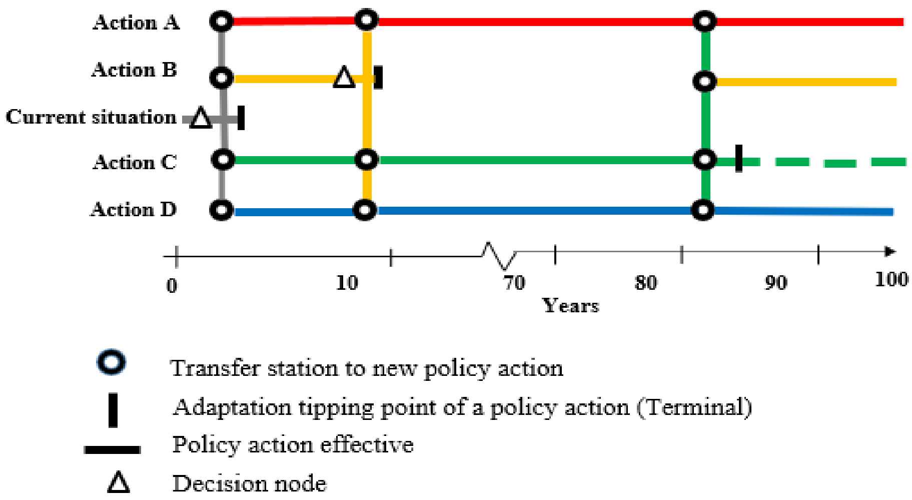

Figure 4. The solutions roadmap by adaptive pathways approach [4].

Step 6: The study conducted direct interviews with experts from Can Tho University and representatives from Departments of Agriculture and Rural Development, Departments of Natural Resources and Environment and Divisions of Agriculture and Rural Development of all districts in Dong Thap province to determine the solutions roadmaps from the solutions map in Step 5. Each expert will provide a different implementation roadmap according to the area of expertise and objective opinion of each expert interviewed. The study has synthesized the solutions roadmaps by different experts and used the Pathway tool to build a roadmap of solutions implementation to meet the objectives of rice production development in the study area by 2030.

Step 7: The study synthesized solutions roadmaps from different experts. Each specialist will have a different roadmap for solutions implement. However, a solutions roadmap must be chosen from different solutions roadmaps in order to support the rice production plan in the study area by 2030. The study applied statistical approaches to choose a solutions roadmap from the data of solutions roadmaps. The solutions roadmaps were chosen where the solutions in the roadmap have the highest selection rate. Specifically, the study arranged solutions following different implementation stages of each roadmap and at each stage, a solution with the highest selection rate will be selected. The process is carried out starting from stage 1 to the end stage. When a solution is chosen in stage 1, it does not count for stage 2, and that is replaced until the final solution.

3. RESULT AND DISCUSSION

3.1. The adaptation roadmaps based on irrigation solutions

Figure 5 shows different roadmaps of solutions based on different experts' suggestions for rice production development in the study area until 2030 according to various viewpoints. Different participants came up with different solutions roadmaps (dark line). The outcome revealed that each solution is equally capable of performing at various phases. Therefore, it's critical to choose and arrange solutions in accordance with the 2030 solution roadmap. Based on the approach of determining solutions roadmaps, the study developed an irrigation solutions roadmap for rice production in the study area by the light line in Figure 5.

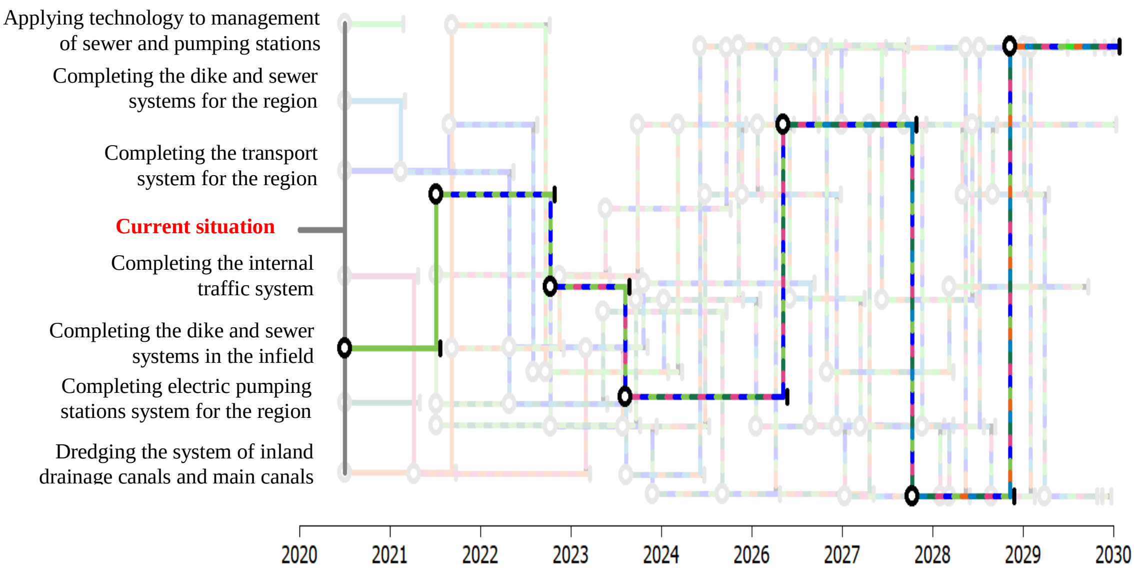

Figure 5. The proposed adaptation roadmap based on irrigation solutions for rice production purpose in the study area to 2030.

In the first two years, it is proposed to finish the system of internal dikes and sluices to assist local farmers in avoiding flooding during the harvesting season when floods occur. Improving internal dikes and sluices systems also aids in the management of water for rice crops. In the next two-year period, it is suggested that the region's transportation system be complete, with the primary service being to improve conditions for rice cultivation. The transportation system makes it easier to travel and transfer goods, allowing the region's production to be linked. The next period (from 5th to 6th year, referred to the year 2020), the solution on completing the infield traffic system will be carried out. The solution is to improve the infield transportation system to facilitate local farmers for the rice cultivation process. In detail, the infield transportation system makes it easier for local farmers to transfer goods to rice fields, lowering production costs. This is especially beneficial for farmers who live far away from their fields. The next period (2026 - 2028), the investigation into the construction of electric pumping stations and the operation of automatic sluice gates is undertaken. This solution will make it easier and more convenient to operate the sluice gates system and pumping station, as well as minimize labor costs while increasing efficiency. The last period (2028 – 2030), dredging the canal system was done to make it more convenient for irrigation water delivery and drainage. Because of the existing state of the canal system, particularly infield canals, it has caused challenges in irrigation for local farmers' rice production activities. Furthermore, the dredging canals system improved transportation for rice commerce in the research area. The solution is executed regularly year by year from now to 2030 according to the level of deposition. In this period, the last solution is applying technology in operating the sewer system and pumping stations. This is a high-tech application solution for remote autonomous irrigation operation and management, assisting the local government on management and adaptation to the abnormal changes in the Mekong River. This goal of the solution is to improve irrigation management efficiency in the study area.

3.2. The adaptation roadmaps based on agricultural solutions

Similar to the roadmap for irrigation solutions, the implementation of the roadmap for agricultural solutions (Figure 6) has been synthesized from the experts' suggestions (dark line) to support the objective of rice production in the study area by 2030. The study has developed an agricultural solutions roadmap (light line in Figure 6) to support rice production in the study area until 2030 in response to the effects of climate change and surface water resources.

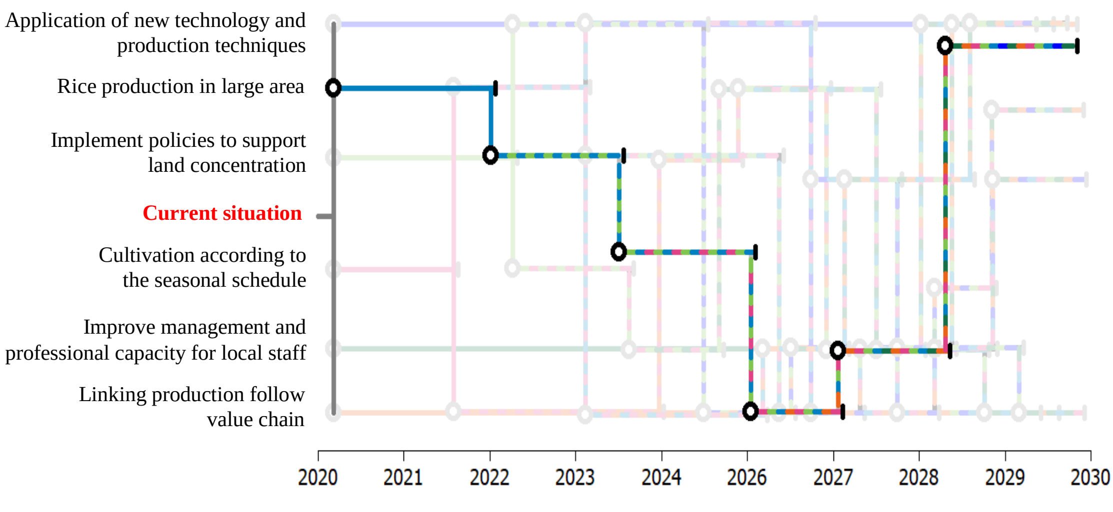

Figure 6. The proposed adaptation roadmap base on agricultural solutions for rice production purpose in the study area to 2030.

In the first two-year period, the solution for large-scale rice production has been implemented. Implementing this method makes it easier to zone agricultural productivity and control irrigation. This solution is suitable with the plan of agriculture development in the study area, as well as in Dong Thap province to 2030. The next two-year period, it is proposed to implement the policy solution for land accumulation. The land accumulation will promote agricultural production (in particular rice production) becoming more efficient due to the unification of applying techniques on a large area that helps to create products with higher quality and quantity than current production activities.

The next period (from 5^{th} to 6^{th} year, referred to the year 2020), the next solution is to carry out the rice production following the seasonal schedule of the local government. The production following the seasonal schedule will help to create a large product quantity and reduce hazards such as diseases, pests, and floods, as well as facilitating irrigation management. Furthermore, combining the production in a large area solution with the seasonal schedule solution will aid in the cultivation process (e.g., irrigation and harvesting) and production linkages. In this period, the solution on cooperating production solution including horizontal linkage (between producing farmers) and vertical linkage (between groups in the production stage) can be done. The linking of rice production will bring more benefits and avoid the impacts of market fluctuations for local farmers. The next period (2026 - 2028), the solution on improving capacity management for local staff in charge of agriculture and irrigation will be conducted. This approach aims to assist the use of technology in rice production and production linkage in the future, particularly in responding to new climate change circumstances and changing surface water resources in the research area. The last period (2028 - 2030), the last solution is to apply new technologies and techniques to rice production. This solution will help minimize labor and enhance the management ability for rice cultivation because most of the stages in the cultivation process are replaced by technological equipment (such as harvesting, irrigation, sowing, etc.). In addition, investing in technology applications in a large production area will be more financially effective than in a small area. Besides, technology investment in rice production after the land accumulation solution will help irrigation management become easier and reduce labor in the rice cultivation process. Furthermore, combining new technology and techniques will support increasing the adaptability of the impacts of climate change and changes in surface water resources during rice production.

3.3. Discussion

The study has developed 02 solutions roadmaps to be referred for rice production strategies in the study area to 2030 by using the DAPP approach. For the irrigation solution roadmap, the solutions focused on construction. For the agricultural solutions roadmap, the solutions focused on policies, technology and techniques in production. In term of analysis process of solutions roadmap for irrigation and agriculture, the study found that, in order to effectively implement the agricultural solutions, the irrigation solutions should be implemented priority. Specifically, the dikes system and pump-stations need to be completed to easily regulate irrigation water that created favorable conditions for technical water-saving irrigation for rice cultivation effectively. In addition, it is possible to conduct a combination between the solutions roadmaps of irrigation and agriculture that helps local farmers tackle difficulties in the rice production process and adapts well to flood variations in the Mekong River and climate change.

According to the original solutions, the participants can develop into a variety of distinct adaptation solutions roadmaps, providing decision-makers with more options for solutions implement. The approach has more advantages to support the decision-makers in choosing the right solution on time as well as selecting suitable roadmaps for rice production in the study area. Furthermore, the solutions were evaluated using various criteria and chosen based on participants that avoid the disadvantages during the implementation process. In addition, through monitoring the process of solutions implement, decision-makers can alter original solutions if the uncertain factors occur or the solution is unsuitable with the initial goal. Furthermore, the solutions roadmap aids in avoiding duplication in solutions execution and diversion from development goals.

The tipping point of solutions is to determine the time solutions implementation as well as the time to change solutions. Besides, the tipping point also aids in avoiding solutions being implemented for longer than they were intended, which will affect the implementation time of other solutions and the development plan. However, determining the tipping point is dependent on the current circumstance, such as financial and human resources as well as the evaluation of stakeholders in the developing solutions roadmap. Therefore, most solutions in this study are unable to exactly predict the tipping point that is only determined by the period time. Furthermore, an important issue about the tipping point shown in this study is that there is a continuous in the implementation of solutions. Specifically, it is not necessary to complete the first solution and then implement the second solution as shown in Figure 5 and Figure 6; it is suitable that the second solution can be implemented in possible time while the first solution is being implemented. The time of solution is a limitation for the solution to be completed.

The recommended solutions, according to the DAPP approach, were the result of a synthesis of expert proposals from many domains, which were then examined in a variety of aspects. In terms of advantages, the solutions were diverse in many fields to address the problem of the study area, and the solutions were analyzed in many different aspects that will help to choose suitable solutions. Furthermore, the solutions roadmap is chosen through a process of evaluation and consensus among many stakeholders, which helps to minimize negative influences throughout the implementation phase. In terms of restrictions, it was difficult to achieve a consensus on the remedies because each expert has differing perspectives. Besides, if unsuitable experts are involved in the proposal, analysis, and evaluation process, this will create many negative signals and lead to difficult to choose suitable solutions for development plans.

To sum up, using the DAPP approach to manage water resources was an appropriate decision, because it support identifying suitable solutions and constructing solutions roadmaps to satisfy the development objectives. The approach follows a progression from identifying problems to propose solutions roadmaps implementation through 10 clearly guided steps, especially the involvement of stakeholders in the process of development solutions roadmaps. Through the implementation solutions roadmap, the monitoring will help the solutions implementation to stay on track with the development purposes. It is especially possible to adapt to uncertainty changes through changing new solutions when the original solution is no longer suitable due to changes in implementation conditions. To effectively apply the DAPP decision approach to surface water resources management in the VMD's flooding area, participants must be experts and clearly understand the development purpose and involvement throughout the process of developing the solutions roadmap. Besides, it is necessary to use many tools and methods to support in choosing the appropriate solutions implementation roadmap.

4. CONCLUSION

The study developed two roadmaps of irrigation and agriculture solutions as examples for the orientation of rice production in the study area to 2030 to adapt to the impacts and uncertain changes in surface water resources and climate. In each group of solutions, the study has arranged and determined time constraint (the tipping point) of solutions implementation. It is necessary to combine solutions roadmaps in implementation process to save the sources of time and economics, and enhance the efficiency of achieving goals in the future. In which, the irrigation solutions should be implemented priority to support agriculture solutions effectively.

The DAPP approach helps to evaluate uncertain factors involved in the implementation of solutions and keep solutions stay on track for long-term purposes. This is a roadmap for dynamically changing solutions, which can be changed when they are no longer suitable for implementation conditions. The DAPP approach supports decision-makers responsible for selecting and implementing the appropriate solutions to adapt to uncertain changes.

The solutions roadmap in this study focused on solving the problems in surface water resource management and rice production development in the study area. Therefore, further studies can apply this approach to extend to other areas in the VMD related to adaptation to uncertainty.

Acknowledgement: The authors of the study would like to express the gratitude to experts at the universities of Delft and Utrecht for providing financial support as well as providing opportunities for the authors to approach the new framework on water resource management. The study thanks the Can Tho University experts for providing professional opinions that assisted in the development of the solutions roadmaps. In addition, the study gives gratitude to the officials of Dong Thap province as well as the farmers in the study area.

CRediT authorship contribution statement. Hong Minh Hoang: Concept, Methodology, Investigation, Data analysis. Nguyen Hong Tin: Reviewing and Editing, Supervision. Dinh Diep Anh Tuan: Reviewing and Editing. Van Pham Dang Tri: Reviewing and Editing, Supervision.

Declaration of competing interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

1. Karlsruhe Institute for Technology (KIT) - IWRM – Integrated Water Resources Management. Int. Conf. Karlsruhe, 2010, pp. 1-436.
2. Kwakkel J. H., Haasnoot M., Walker W. E. - Developing dynamic adaptive policy pathways: a computer-assisted approach for developing adaptive strategies for a deeply uncertain world, Clim. Change. **132 (**2015) 373-386.
3. Walker W. E., Marchau V. A. W. J., Swanson D. - Addressing deep uncertainty using adaptive policies: Introduction to section 2, Technol. Forecast. Soc. Change. **77** (2010) 917-923.
4. Haasnoot M., Middelkoop H., Beek E. Van, Deursen W. P. A. Van - A method to develop management strategies for an uncertain future, Sustain. Dev. **381 (**2011) 369-381.
5. Gohari A., Mirchi A., Madani, K. - System Dynamics Evaluation of Climate Change Adaptation Strategies for Water Resources Management in Central Iran, Water Resour Manag. **31** (2017) 1413-1434.
6. Kotir J. H., Smith C., Brown G., Marshall N., Johnstone R. - A system dynamics simulation model for sustainable water resources management and agricultural development in the Volta River Basin, Ghana. Sci. Total Environ. **573 (**2016) 444-457.
7. Sun Y., Liu N., Shang J., Zhang J. - Sustainable utilization of water resources in China: A system dynamics model, J. Clean. Prod. **142** (2017) 613-625.

8. Mun J. - Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Wiley Finance, 2006, pp. 1-647.
9. Buurman J., Babovic V. - Design of adaptive policy pathways under deep uncertainties - An approach to climate change adaptation, Coping with Uncertain. Ambiguity Int. Conf. Uncertain. Policy Des. Res., 2014, pp. 1-18.
10. Buurman J., Babovic V. - Adaptation Pathways and Real Options Analysis: An approach to deep uncertainty in climate change adaptation policies, Policy Soc. **35** (2016) 137-150.
11. Kwakkel J. H., Haasnoot M., Walker W. E. - Comparing Robust Decision-Making and Dynamic Adaptive Policy Pathways for model-based decision support under deep uncertainty, Environ. Model. Softw. **86 (**2016) 168-183.
12. Groves D. G., Fischbach J. R., Bloom E., Knopman D., Keefe R. - Adapting to a Changing Colorado River - Making Future Water Deliveries More Reliable Through Robust Management Strategies, RAND Environ. Energy, Econ. Dev. Progr. (2013) 1-102.
13. Dittrich R., Wreford A., Moran D. - A survey of decision-making approaches for climate change adaptation: Are robust methods the way forward?, Ecol. Econ. **122 (**2016) 79-89.
14. Haasnoot M., Middelkoop H., Offermans A., van Beek E., van Deursen W. P. A. - Exploring pathways for sustainable water management in river deltas in a changing environment, Clim. Change. **115 (**2012) 795-819.
15. Thissen W., Kwakkel J., Mens M., van der Sluijs J. - Dealing with Uncertainties in Fresh Water Supply: Experiences in the Netherlands, Water Resour Manag. **31** (2017) 703-725.
16. Kwakkel J. H., Walker W. E., Marchau V. A. W. J. - Adaptive Airport Strategic Planning, Eur. J. Transp. Infrastruct. Res. **10 (**2010) 249-273.
17. Hamarat C., Kwakkel J. H., Pruyt E. - Adaptive Robust Design under deep uncertainty, Technol. Forecast. Soc. Change. **80** (2013) 408-418.
18. Walker W. E., Haasnoot M., Kwakkel J. H. - Adapt or perish: A review of planning approaches for adaptation under deep uncertainty, Sustain. **5** (2013) 955-979.
19. Kwakkel J. H., Pruyt E. - Exploratory Modeling and Analysis, an approach for model-based foresight under deep uncertainty, Technol. Forecast. Soc. Change. **80 (**2013) 419-431.
20. Li X., Liu J. P., Saito Y., Nguyen V. L. - Recent evolution of the Mekong Delta and the impacts of dams, Earth-Science Rev. **175** (2017) 1-17.
21. To Quang Toan, Tang Duc Thang, Tran Ba Hoang, Le Manh Hung, Duong Xuan Minh - Impact of climate change, upstream development, internal development on the Mekong Delta, challenges and solutions, Workshop on solutions to control salinity and fresh storage for production and people in the Mekong Delta, 2016, pp. 1-13.
22. Ogston A. S., Allison M. A., Mullarney J. C., Nittrouer C. A. - Sediment- and hydro-dynamics of the Mekong Delta: From tidal river to continental shelf, Cont. Shelf Res. **147** (2017) 1-6.
23. Brunier G., Anthony E. J., Goichot M., Provansal M., Dussouillez P. - Recent morphological changes in the Mekong and Bassac river channels, Mekong delta: The marked impact of river-bed mining and implications for delta destabilisation, Geomorphology. **224** (2014) 177-191.
24. Dang T. D., Cochrane T. A., Arias M. E., Tri V. P. D. - Future hydrological alterations in

the Mekong Delta under the impact of water resources development, land subsidence and sea level rise, J. Hydrol. Reg. Stud. **15** (2018) 119-133.

25. Manh N. Van Dung, Hung N. V., Kummu N. M. - Future sediment dynamics in the Mekong Delta floodplains: Impacts of hydropower development, climate change and sea level rise, Glob. Planet. Change. **127 (**2015) 22-33.
26. Turner S., Pangarre G., Mather R. J. - Water Governance: A Current Situation in Laos, Cambodia and Viet Nam, Mekong Regional Water Dialogue, Publication No. 2 . Gland, Switzerland IUCC, 2009, pp. 1-67.
27. Tri V. P. D., Popescu I., Van-Griensven A., Solomatine D. - A study of the climate change impacts on fluvial flood propagation in the Vietnamese Mekong Delta, Hydrol. Earth Syst. Sci. Discuss. **9 (**2013) 7227-7270.
28. To Van Truong - Looking back on 40 years of irrigation in the Mekong Delta, Viet Nam Association of Large Dams and Water Resources Development, 2015, pp. 1-3.
29. Sagris T., Tahir S., Möller-Gulland J., Quang N. V. - Viet Nam: Hydro-Economic Framework for Assessing Water Sector Challenges, 2030 Water Resour. Gr., 2017, pp. 1-124.
30. Haasnoot M., Kwakkel J. H., Walker W. E., Maat J. - Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world, Glob. Environ. Change. **23** (2013) 485-498.
31. Decree No. 01/2020/ND-CP - Amending and supplementing a number of articles of the Government's Decree No. 84/2015/ND-CP dated September 30, 2015 on investment supervision and evaluation, 2020.
32. Dong Thap Province People's Committee - Adjustment of Dong Thap Irrigation Development Planning to 2020 and Orientation to 2050 (adaptation to flood and climate change - sea level rise), 2018.