

Five-dimensional Strategic Environmental Assessment (SEA) Action Framework Toward Sustainable River Basin Management Under Climate Change

Warangluck Na sorn^{1,2}, Sanya Sirivithayapakorn^{2*}, Sucheela Polruang²,
Narumol Vongthanasunthorn^{2,3}

¹Department of Royal Irrigation, Bangkok, 10300, Thailand

^{2*}Department of Environmental Engineering, Faculty of Engineering, Kasetsart University, Bangkok, 10900, Thailand
(Corresponding Author)

³Faculty of Science and Engineering, Saga University, Saga, Japan

warangluck.n@ku.ac.th, fengsys@ku.ac.th*, fengslpo@ku.ac.th, and si4430@cc.saga-u.ac.jp

Abstract. *Although strategic environmental assessments (SEA) for river basin management are being implemented in many countries, there is considerable variation in approaches, institutional arrangements, impact assessment tools, scope, and procedures. Moreover, the extent to which SEA addresses sustainability and is anchored in the United Nations Sustainable Development Goals (SDGs) depends on various factors, particularly the impacts of climate change. This research proposes an SEA action framework for sustainable river basin management under climate change with the integration of the SDGs' five dimensions People, Planet, Prosperity, Peace, and Partnership (5Ps). A selection of SEA tools to assess the impacts of climate change along the 5Ps is presented. A systematic literature review and content analysis are carried out to establish the SEA action framework and identify the SEA tools. A systematic literature review and content analysis was conducted, e.g., of peer-reviewed research publications and publicly available information and guidance documents, to establish the SEA framework for action and identify SEA tools. The proposed framework provides more comprehensive and applicable SEA for sustainable river basin management and for assessing the potential impacts of climate change.*

Received by	01 September 2023
Revised by	18 October 2023
Accepted by	24 October 2023

Keywords:

Environmental impact; global warming; SEA guidance; United Nations Sustainable Development Goals (SDGs); water crisis; watershed

1. Introduction

Recent decades have witnessed worsening water shortage, inequitable water distribution, and water disasters as a result of climate-induced extreme weather events despite attempts by governments to invest in sustainable water resources management and technology [1, 2]. The European

Union (EU) has been paying attention to mainstreaming climate change into its policies since it launched the European Climate Change Program in 2005, which focuses on impacts and adaptation. Climate change is also part of the Flood Risk Management Directive; it is one of the main issues to be considered when Member States carry out an initial flood risk assessment and prepare the risk management plans. Similarly, climate change must be taken into account in water management planning in relation to droughts and water scarcity [3]. Besides, now included in the United Nations (UN) 17 Sustainable Development Goals (SDGs), are two SDGs aiming at tackling water-related issues (i.e., SDGs 6 and 14) [4]. As a result, climate change and its potential impacts should be taken into consideration in the management of water resources.

Strategic environmental assessment (SEA) is a process for evaluating the environmental implications and the sustainability of a proposed policy, plan or program (PPP); and provides means for exploring cumulative effects and adequately address them at the earliest stage of decision making along economic and social considerations [5-7]. This practice has begun in the United States, particularly in the state of California, and expanded to countries such as Australia, Canada, and New Zealand, as well as in the EU. For the SEA river basin district, the European Commission [8] has stated that the SEA directive should be considered in the implementation of the Water Framework Directive for river basin management plans.

Although more and more countries are implementing river basin management in the form of SEA, the extent to which SEA addresses sustainability and achieves the intended SDGs goals depends on a variety of factors in each area, including the skills available among practitioners, the flexibility afforded by decision makers, a range of assessment tools available at SEA, and the existing guidance documents [9-16]. There are very few guidance documents that thoroughly consider the risks of climate change because management of supply, demand, and interrelationship between emissions in different areas and the effects of

climate change (e.g., extreme floods and droughts) are vary considerably with location. [17-21]. There is no single assessment tool that is ideal for all SEA, so there is a need to develop a specific and comprehensive guide, especially in countries that do not yet have a SEA guide for a specific sector such as river basin management [22].

The traditional concept of sustainable development originated around three decades ago is still a goal setting for a country development [23]. The same sustainability concept has also been implemented in the SEA, even though the SEA concepts and applications have evolved rapidly over the past decade [24]. Most SEA guidance conceptually addresses the climate change but does not provide a comprehensible concept that allows extensive analyses on the sustainable aspect of the SEA process [22, 25, 26]. A recently proposed 5 dimensions of the SDGs, the United Nations Agenda: People, Planet, Prosperity, Peace, and Partnership (5Ps), provides a comprehensible concept that allows extensive analyses on the sustainable aspect of the SEA process.

The aims of the five dimensions (5Ps) are as follows: Planet (Natural Resources): To protect natural resources and climate for the current and future generations; People (Livelihood): To improve livelihood and end poverty and to ensure equal access to healthcare and education; Peace (Social and Institutions): To foster peaceful, just and inclusive societies, with priority given to humanitarian issues arising from water scarcity, inequitable water distribution, and water use; Prosperity (Economy and Technology): To ensure that all people can lead prosperous and fulfilling lives in which economic and technological progress occurs in harmony with nature; and Partnership (Participation): To prioritize the needs of the poorest and most vulnerable with the participation of all stakeholders and all people [4].

Specifically, this research proposes an SEA action framework for sustainable river basin management under climate change along the five dimensions of the UN SDGs: People, Planet, Prosperity, Peace, and Partnership (5Ps). A selection of corresponding SEA tools to assess the potential impacts of climate change on river basins is provided together with the proposed framework. This makes it more comprehensive and applicable for assessing the potential impacts of climate change on river basins. Especially in those countries that do not yet have a specific guide for river basins.

2. Research Methodology

This research conducts a systematic literature review and content analysis to establish an SEA action framework for sustainable river basin management under climate change. Abbreviations that are used throughout the manuscript were listed in Table 1. The articles that meet all inclusion criteria as follows Table 2 will be included in the review process. The SEA actions for sustainable river basin management and the available SEA tools were abstracted.

The reviewed literature includes peer-reviewed research publications (69) and publicly available information

and guidance documents (24), totaling 93 publications and documents. The publications and guidance documents are in the field of the impacts of climate change on river basins (18), sustainable river basin management (22), SEA process (27), and SEA tools (26).

The peer-reviewed publications are retrieved from citation databases of the Web of Science, Elsevier’s Scopus, and Google Scholar [25]. No date restrictions are imposed on the search such that the search results are comprehensive and illustrate the current and the increasing relevance of the topics. The publicly available information includes climate change reports, legislation, SEA guidance documents, and guidance documents on sustainable river basin management. The reports and guidance documents are published by local and international institutions, such as the United Nations (UN), United Nations Development Program (UNDP), European Union (EU), Organization for Economic Cooperation and Development (OECD), the World Bank Organization, the Intergovernmental Panel on Climate Change (IPCC), the U.S. National Environment Management Authority (NEMA), the U.S. Environmental Protection Agency (EPA).

Abbreviations	Description
5Ps	People, Planet, Prosperity, Peace, and Partnership
EPA	U.S. Environmental Protection Agency
EU	European Union
IPCC	The Intergovernmental Panel on Climate Change
NEMA	U.S. National Environment Management Authority
OECD	Organization for Economic Cooperation and Development
PPP	Policy, Plan or Program
SDGs	Sustainable Development Goals
SEA	Strategic Environmental Assessments
UN	United Nations
UNDP	United Nations Development Program

Table 1 List of abbreviations used in the manuscript.

The relevant keywords	Inclusion criteria
Climate change impacts on river basins	Describes the impacts of climate change on risks to human society and natural ecosystems in river basins that are expected to be increasingly disruptive in the coming decades. e.g., change of seasons and extreme events (floods and drought).
Sustainable river basin management	Describes components, plans, or activities contribution to sustainable river basin management.
Strategic Environmental Assessment	The current concept and process of SEA from various national guidance documents and SEA Processes that support climate change.
Tools of SEA	Tools or methods that used in current SEA process from various national guidance documents and capable of addressing climate change.

Table 2 Inclusion criteria for material eligibility

Fig. 1 shows the research scope and the proposed 5P-based SEA framework for sustainable river basin management. The proposed SEA action framework is developed by integrating the five dimensions of the UN

SDGs (People, Planet, Prosperity, Peace, and Partnership) into the four phases of the SEA process; implementing the SEA; informing and influencing decisions; and monitoring and evaluation [27], to formulate the 5P-based SEA action framework for sustainable river basin management.

The impacts of climate change and their corresponding SEA tools to assess and predict the impacts of climate change on river basins are gathered, classified, and presented with the proposed framework by searching peer-reviewed publications and general guidance documents for the common tools that were mentioned frequently that are capable of assessing climate change impacts on river basins [1, 18, 24, 28-32].

The SEA tools for assessing and predicting the impacts of climate change on river basins are summarized and categorized into two groups: qualitative and quantitative SEA tools. The SEA tools will be selected according to the 5Ps of *identify and predict potential impacts* task as part of the second SEA phase (i.e., implementing the SEA). illustrates the scope of this research and the proposed 5P-based SEA framework.

3. Results and Discussion

The review of 93 peer-reviewed research publications and publicly available reports and guidance documents reveals three essential findings. First, the major impacts of climate change on river basins include unprecedented floods and severe droughts [18, 21, 33-36], consistent with the IPCC reports. An increasing number of studies have attached greater importance to climate change-induced extreme weather events and the SEA process [19, 37, 38]. Furthermore, governments have increasingly integrated SEA into the policy, plan or program preparation process from the early stages [10, 39].

Second, most of the general SEA guides for some countries that do not have river basin SEA guidance are too general to apply. It is complicated to identify the SEA tasks or activities associated with the various phases of the SEA process [22, 40, 41]. Besides, there exists no discussion in the current guidance documents as to the applicability of the SEA tools to assessing the potential impacts of climate change [42-44].

Third, similar to the general SEA guidance documents, those pertaining to river basin management (i.e., specific guidance documents) are too generic to be of use. In addition, a lack of uniformity exists between the national-level, regional-level, and area-specific SEA guidance documents. For that reason, the SEA activities and tool selection are largely predicated on the subjective views and experiences of practitioners at different levels [45].

Table 3 presents the 5P-based SEA framework for action for sustainable river basin management. It serves as a guide for the formulation of sustainable river basin policy. It should be noted that the 5P approach may also be applicable to other resource-related PPPs for areas experiencing conflict or resource stress and scarcity. It lists the 5P-based activities associated with the four SEA phases for sustainable river basin management.

In the first phase (i.e., establishing the context for the SEA), SEA practitioners examine relevant data on sustainable river basin management along the 5P dimensions (People, Planet, Prosperity, Peace, and Partnership); and identify all stakeholders. The practitioners then collaborate with the stakeholders to establish the SEA goals, with greater importance attached to natural resources at risk and the most vulnerable groups of people. If possible, there should be participation at the initial phase, requiring consultation and updating by the parties. This would lead to more open and transparent decision-making, greater representativeness, and early identification of conflicts to reduce the risk of litigation by affected stakeholders. This in turn would help avoid delays in implementation [27, 46].

The second phase (implementing the SEA) involves gathering historical data on floods, droughts, extreme weather events as well as water demand. The observed (historical) data are used to determine the levels of water stress and to project the potential impacts of climate change on river basins. The mitigation strategies are subsequently formulated (i.e., measure identification). Early warning systems and water-sensitive urban planning or redesign through more effective policies, multilevel flood and drought models, and data-driven water quantity and quality models are new technologies that increase the effectiveness of mitigation strategies [47]. In addition, coordination and collaboration with local governments is essential for an effective response to climate change adaptation development [48].

The third phase (informing and influencing decision) entails making recommendations to the decision makers under three scenarios: (i) with the existing water infrastructure, (ii) with improved water infrastructure, and (iii) with new water infrastructure in addition to the existing one. The recommendations should be formulated along the 5P dimensions.

In the fourth phase, monitoring and evaluation mechanisms are put in place to minimize the environmental impacts from the implementation of the policy, plan, or program; and to ensure the SEA goals are materialized. The mechanisms enable the timely identification of negative impacts and implementation of corrective action.

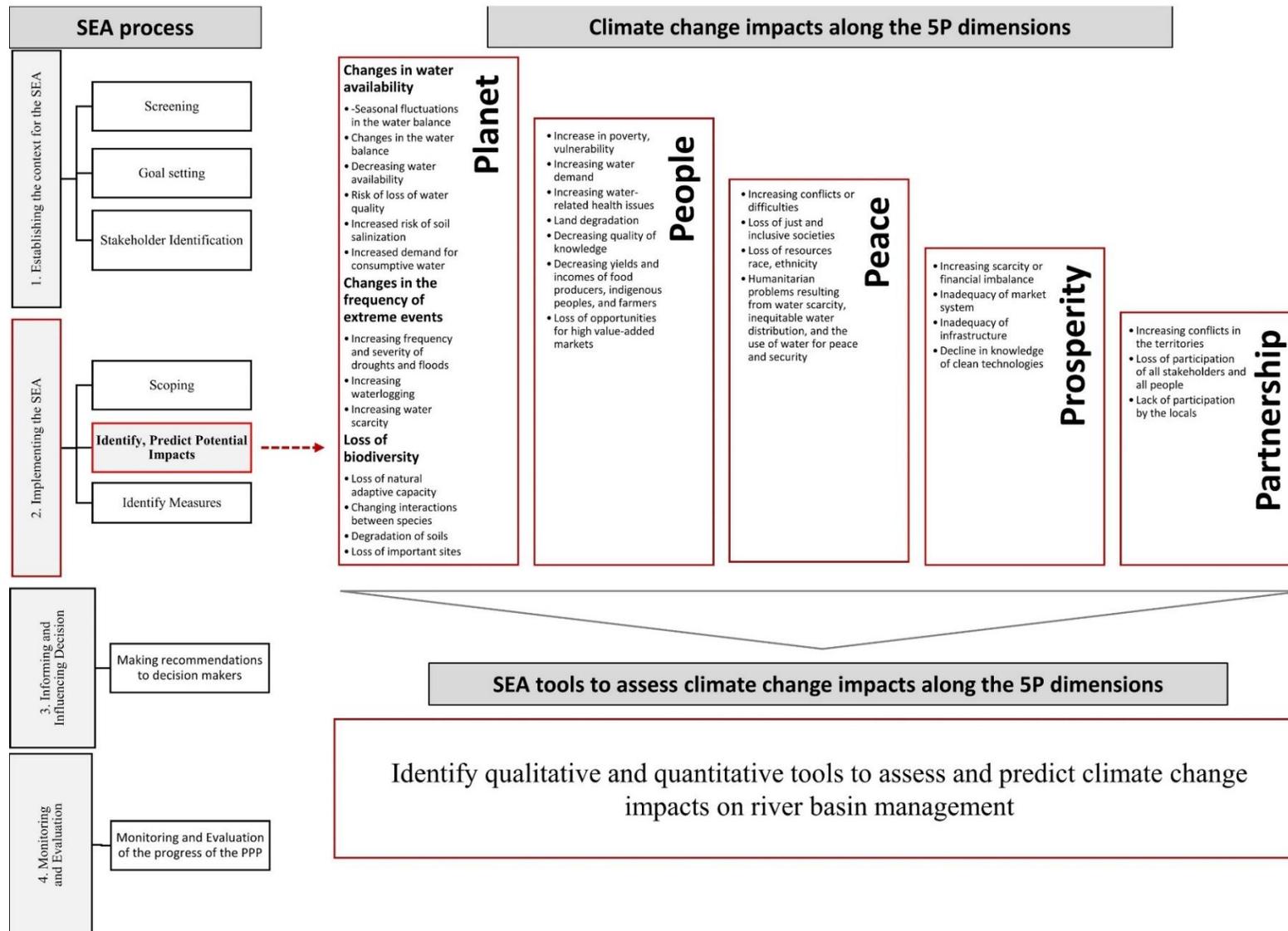


Fig. 1 The research scope and the proposed 5P-based SEA framework for sustainable river basin management.

SEA Process		Sustainable river basin management activities					References
		Planet (Natural resources)	People (Livelihood)	Peace (Social and institutions)	Prosperity (Economy and technology)	Partnership (Participation)	
Phase 1: Establishing the context for the SEA	Screening	* Screen for natural resources to protect for present and future generations.	* Gather data on livelihoods and accessibility to healthcare and education.	* Determine conflicts in societies and humanitarian issues arising from water scarcity or floods, inequitable water distribution, and water use.	* Find out whether people lead prosperous and fulfilling lives where economic and technological progress occurs in harmony with nature.	* Gather data on the poorest and most vulnerable with the participation of all stakeholders and all people.	[9, 10, 26, 34, 37, 38, 44, 49-68]
	Goal setting	* Ensure availability and sustainable management of water for all; and take action to mitigate climate change and its impacts.	* Protect the poorest and most vulnerable from inequitable water distribution, water-related natural disasters, and climate-induced extreme weather events.	* Foster peaceful and inclusive societies for sustainable development; to provide access to justice; and to build effective, accountable, and inclusive institutions at all levels.	* Promote sustainable economic growth and access to affordable, reliable, sustainable water use.	* Encourage active participation and build a good rapport.	
	Stakeholder Identification	* Identify vulnerable natural resources.	* Identify people affected by inequitable water distribution, water-related natural disasters, and climate-induced extreme weather events.	* Communicate to stakeholders the goals of SEA in the context of the proposed policies, plans or programs (PPP). * Take account of the water resources development priorities.	* Identify direct economic loss attributable to water-related disasters in relation to global gross domestic product (GDP).	* Identify and engage stakeholders who are the most exposed to inequitable water distribution, water-related natural disasters, and climate-induced extreme weather events. * Brainstorm and inform SEA proposal to solicit comments and concern affected stakeholders and relevant parties.	[46, 60, 69, 70]

SEA Process		Sustainable river basin management activities					References
		Planet (Natural resources)	People (Livelihood)	Peace (Social and institutions)	Prosperity (Economy and technology)	Partnership (Participation)	
Phase 2: Implementing the SEA	Scoping	<ul style="list-style-type: none"> * Identify baseline data: hydrological data of river basins, physiography, climate, geology, and forests. * Identify key problems or sensitive areas, critical habitats, and valuable ecosystem components. * Identify the proportion of water bodies with good water quality. * Identify the proportion of forest land to total land area. * Identify the proportion of areas important for terrestrial and freshwater biodiversity. * Identify the proportion of degraded areas to total land area. * Identify the proportion of protected areas important for biodiversity. * Identify the proportion of wildlife that is poached or illegally traded. 	<ul style="list-style-type: none"> * Identify demographics such as fertility, mortality, household size, population density, education, and health. * Identify the number of deaths, missing persons, and those directly affected by water-related disasters. * Identify the proportion of population living below poverty line and/or without access to consumptive water. * Identify the proportion of population with secure property rights. * Identify livelihoods of river basin communities and source of income. 	<p><u>Society</u></p> <ul style="list-style-type: none"> * Identify cultural, religious structures and ethnic groups. * Identify land use and common property. <p><u>Institution</u></p> <ul style="list-style-type: none"> * Ensure that the objectives of the PPP are consistent with the country- and/or region-level river basin management policy. * Establish a specific and realistic timeframe. * Establish a management team/steering committee and appoint an SEA coordinator/manager. * Identify the extent of integrated water resources management. * Identify related government agencies, laws, and human rights. 	<p><u>Economy</u></p> <ul style="list-style-type: none"> * Determine the annual growth rate of GDP per capita. * Determine the percentage of individuals aged 15-24 who receive no formal education. * Determine the percentage of total government spending on water services. * Determine international financial assistance to support clean energy research and development (R&D) and renewable energy. * Determine R&D expenditures as a percentage of GDP. <p><u>Technology</u></p> <ul style="list-style-type: none"> * Identify current infrastructure. * Compile tools, strategies, and legislation for river basin management. 	<ul style="list-style-type: none"> * Inform about the SEA process to bring key stakeholders together to agree on problem, objectives, alternatives, and quality control measures. * Share information of transboundary basin with operational agreement on water cooperation. 	[71-73]
	Identify, Predict Potential Impacts	<ul style="list-style-type: none"> * Identify trends in natural resources degradation based on temperature-precipitation variability, transition times, runoff, sea level rise and storm surges, and flooding. * Assess frequency of droughts, soil fertility, and deforestation. * Identify trends in water use efficiency over time. * Identify trends in natural resources at risk. * Identify trends in levels of water stress: freshwater withdrawals relative to available resources. 	<ul style="list-style-type: none"> * Identify livelihood trends (time series data on employment/employment structure/poverty dynamics/entry and exit by occupation). * Identify activities likely to have impacts on river basins, e.g., water use, deforestation, land degradation, land speculation, and overfishing. * Predict likely impacts and the response of various stakeholders. 	<p><u>Society</u></p> <ul style="list-style-type: none"> * Identify trends in race and ethnicity distribution. * Identify trends in elite formation and competing for land claims. <p><u>Institution</u></p> <ul style="list-style-type: none"> * Identify the percentage of local governments that adopt and implement area-specific disaster risk reduction strategies consistent with national disaster risk reduction strategies. 	<ul style="list-style-type: none"> * Assess capacity of water supply. * Assess vulnerability of water supply * Determine the proportion of water resource use from a variety of sources. * Identify the proportion of irrigated land to productive and sustainable agriculture. * Identify trends in water use and resource use: deforestation, land degradation, land speculation, and overfishing. 	<ul style="list-style-type: none"> * Educate the stakeholders and public about the impacts of water-related disasters on physical and mental health. * Emphasize stakeholder and all relevant party participation, including blunt impact assessment and soliciting feedback from stakeholders and the public. 	[1, 18, 20, 21, 25, 28-32, 36, 53, 60, 69, 74-96]

SEA Process		Sustainable river basin management activities					References
		Planet (Natural resources)	People (Livelihood)	Peace (Social and institutions)	Prosperity (Economy and technology)	Partnership (Participation)	
Phase 3: Informing and Influencing Decision	Identify Measures	<ul style="list-style-type: none"> * Identify measures to protect at-risk natural resources. 	<ul style="list-style-type: none"> * Identify individual-level water-related risks and adaptive measures. * Assess and adopt individual-level adaptive measures to water-related risks. * Provide adaptive training to vulnerable people, including people with disabilities, indigenous peoples, and children in vulnerable situations. * Ensure that positive outcomes are maximized instead of focusing on minimizing harm from negative impacts. 	<p><u>Society</u></p> <ul style="list-style-type: none"> * Identify community-level water-related risks and adaptive measures. * Provide full and productive employment and decent work for all. <p><u>Institution</u></p> <ul style="list-style-type: none"> * Provide recommendations for avoiding and/or solving conflicts arising from water issues among stakeholders. 	<ul style="list-style-type: none"> * Increase financial support for healthcare and medical research, especially for diseases caused by water pollution and soil contamination. * Increase the efficiency of water use. * Strengthen economic and social cohesion for future generations. * Adopt new technologies to improve efficiency and productivity. * Promote sustainable economic growth. * Ensure access to affordable, reliable and sustainable water for all. * Build infrastructure; promote inclusive and sustainable irrigation; and encourage innovation. 	<ul style="list-style-type: none"> * Make aware of the water-related risks, in particular the most vulnerable. * Build a good rapport between communities and local government. * Attach greater emphasis to the importance of water reuse and how to achieve net-zero water use at international conferences on water management. 	[97-101]
	Making recommendations to decision makers	<ul style="list-style-type: none"> * Recommend legislation and adequate funding for the prevention or control of invasive species. 	<ul style="list-style-type: none"> * Present potential impacts to all stakeholders. * Recommend alternatives for consideration; methods for analysing key issues; and sources of relevant data. * Recommend livelihood support through barter, unpaid labour, work sharing, caretaking, project compensation, cash transfers, pensions, and gifts. 	<ul style="list-style-type: none"> * Present potential impacts in a straightforward manner. 	<ul style="list-style-type: none"> * Recommend evaluation process and provide financial compensation. * Mobilize financial resources. 	<ul style="list-style-type: none"> * Resolve conflicts between stakeholders and recommend dispute settlement. 	[34, 49, 77, 102-110]

SEA Process		Sustainable river basin management activities					References
		Planet (Natural resources)	People (Livelihood)	Peace (Social and institutions)	Prosperity (Economy and technology)	Partnership (Participation)	
Phase 4: Monitoring and Evaluation	Monitoring and Evaluation of the progress of the PPP	* Review progress on PPP and sustainable river basin management. * Review the number of contributions, long-term strategies, adaptation plans, and communications on adaptation as reported.					[37, 38, 50, 52, 54-57, 59, 60, 65, 67, 84]

Table 3 The 5P-based SEA action framework for sustainable river basin management.

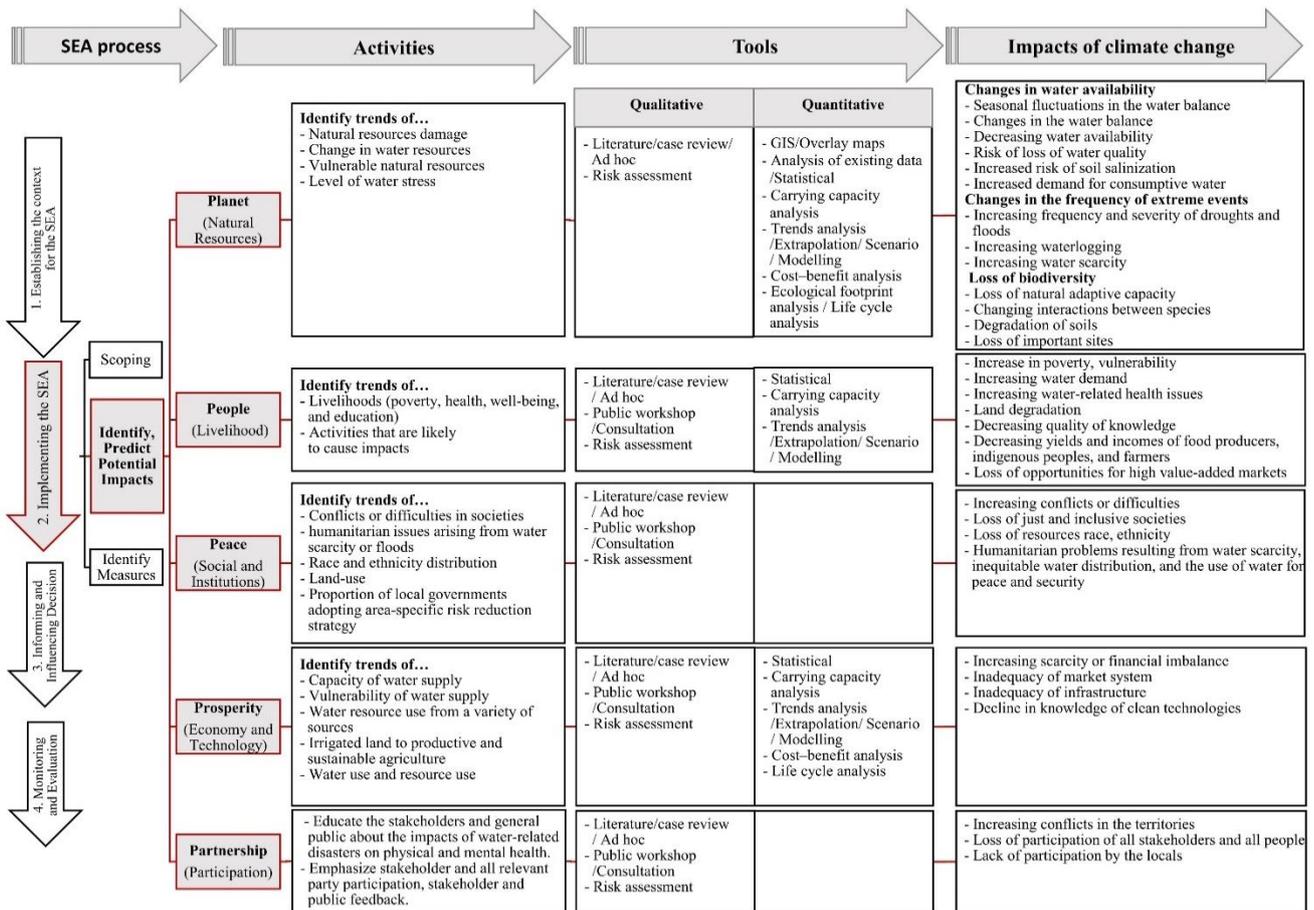


Fig 2. The SEA tools to assess potential climate change impacts on river basins along the 5P dimension.

Fig.2 presents the SEA tools to assess the potential impacts of climate change on river basins along the 5P dimensions (People, Planet, Prosperity, Peace, and Partnership). As illustrated in, the SEA tools belong to the *identify and predict potential impacts* task under the second SEA phase (i.e., implementing the SEA).

The tools are gathered from the SEA guidance documents and categorized into two groups: qualitative and quantitative tools [12, 26-28, 42-44, 87, 111-113]. The qualitative SEA tools are necessary to observe specific situations [54, 114-116]. These tools are based on the experience, judgment, and wisdom of the members of the SEA team. Examples of the qualitative SEA tools are literature case study, ad hoc analysis, and risk assessment. In practice, the SEA practitioners should first adopt the qualitative tools to assess the potential impacts along the 5P dimensions. Given the significance of natural resources for human life, previous research on climate change impacts on river basins places considerable emphasis on the planet dimension (natural resources) [117]. A literature review and ad hoc analysis are a qualitative review of scientific sources on a particular topic. Both qualitative tools provide an overview of current knowledge and case studies in the field and identify relevant theories, methods, and gaps in existing assessment [118]. The risk assessment tool is used to rank

the risks to determine which should be addressed first and for which the largest countermeasure budget should be allocated. It consists of both qualitative and quantitative data, as the tool relies on interview responses (qualitative data) such as the Delphi method, brainstorming, storyboarding, focus groups, surveys, questionnaires, checklists, and interviews [118-120]. and statistical analysis (quantitative data) specific to a particular community to assess and predict the potential risks.

The quantitative SEA tools used to assess the climate change impacts on river basins [116, 121] include geographic information system (GIS), overlay maps, statistical analysis, carrying capacity analysis, hydrologic factor prediction, trends analysis, extrapolation, scenario, modelling, cost benefit analysis, ecological footprint analysis and life cycle analysis. The process may begin with using GIS and overlay maps to delineate the area to and then performs statistical and carrying capacity analyses using the existing data to determine the water resources carrying capacity (WRCC) [122, 123] of a river basin under the predicted climate change impacts. [124-127]. Practitioners must use quantitative SEA hydrologic factor prediction tools with a water resource account to analyses the climate change impacts on river basins, for example to predict fluctuation of the surface runoff as a result of climate change that could lead to severe flood and drought [128-131]. Then using the

trend analysis, extrapolation, mathematical modelling (stochastic or deterministic) to predict climate change impacts on the river basin [132]. The prediction or forecasting can be carried out with the applications of machine learning and remote sensing through technologies of choice available in various industries [128, 133-137].

Quantitative tools for predicting climate change impacts should use statistical data analysis with scenario modelling [114]. An example of scenario modelling that provides reliable and comprehensive predictions is the scenario modelling developed by the IPCC [138] that considers changes in the hydrological cycle and presents representative concentration pathways (RCPs) of the climate change scenario to enable predictions [139]. Cost-benefit analyses, ecological footprint analyses, and life-cycle analyses can help decide on the best technical solutions or alternatives in water resource use with economic and technological aspects of water resource management [140, 141].

Of relevance is public consultation which is the qualitative tool conventionally employed to encourage participation of stakeholders and gatekeepers [64, 142]. By definition, the gatekeepers refer to individuals and/or groups who control access to the people or resources needed in the development of a social and behavior change communication strategy. In a public consultation workshop, stakeholders and gatekeepers are invited to a brainstorm session to solicit their views on the proposed PPP and to build a consensus. It should also include soliciting feedback, input, and participation from stakeholders and the public, with the most important participation being "active listening to stakeholders." It allows parties with different mandates on natural resources and other issues to make lasting commitments and reach agreements with a long-term perspective [46, 143].

4. Conclusion

This research proposes an SEA action framework for sustainable river basin management under climate change along the five dimensions of the UN SDGs: Planet, People, Peace, Prosperity, and Partnership (5Ps). In addition, the SEA tools along the 5P dimensions are presented to assess the potential impacts of climate change on river basins, complementing the common tools used in the SEA process. In this study, a systematic literature review and content analysis are undertaken to establish the SEA action framework and identify the SEA tools. The reviewed literature includes peer-reviewed research publications and publicly available information and guidance documents. The proposed 5P-based SEA action framework consists of four phases: establishing the context for the SEA; implementing the SEA; informing and influencing decisions; and monitoring and evaluation. The SEA tools to assess the impacts of climate change on river basins are categorized into two groups: qualitative and quantitative SEA tools. The SEA tools belong to the *identify and predict potential impacts* task of the second SEA phase. Essentially, the proposed 5P-based SEA action framework for sustainable

river basin management under climate change encompasses the three pillars of sustainability: environmental, social, and economic. Essentially, the proposed 5P-based SEA action framework for sustainable river basin management under climate change is based on the 5P dimensions of UN, which comprise the three pillars of sustainability: environmental, social, and economic. Therefore, unlike the existing SEA frameworks that are based only on the three pillars of sustainability, it is more comprehensive and emphasize suited to assess the potential impacts of climate change on river basins.

5. Acknowledgement

This paper was supported by the Ph.D. Scholarship from Agricultural Research Development Agency (Public Organization), Thailand.

6. References

- [1] Intergovernmental Panel on Climate Change, "Climate Change 2021 The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the IPCC," the IPCC, Switzerland., 2021.
- [2] United Nations. "United Nations 2023 Water Conference Global Online Stakeholder Consultation: Themes for Interactive Dialogues." Division for Sustainable Development Goals (DSDG) of the Department of Economic and Social Affairs (UN DESA). <https://sdgs.un.org/conferences/water2023> (accessed 1-December-2022).
- [3] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, 2020.
- [4] United Nations. "Transforming our world: The 2030 Agenda for Sustainable Development A/RES/70/1." www.sustainabledevelopment.un.org (accessed 1-December-2022).
- [5] M. d. R. Partidário, "Strategic Environmental Assessment Better Practice Guide," Portuguese Environment Agency and Redes Energéticas Nacionais (REN), SA, 2012.
- [6] K. Hameed, "Strategic Environmental Assessment for Better Flood Risk Planning in Pakistan," (in English), Eng.D. no. 27610295, p. 307, 2017 2017.
- [7] T. B. Fischer and A. González, *Handbook on Strategic Environmental Assessment (27 chapters)*. Edward Elgar, Cheltenham, , 2021.
- [8] (2001). *European Commission: Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment*.
- [9] R. Théritel, "Strategic environmental assessment in Central Europe," *Project Appraisal*, vol. 12, no. 3, pp. 151-160, 1997, doi: 10.1080/02688867.1997.9727054.
- [10] V. Lobos and M. d. R. Partidário, "Theory versus practice in Strategic Environmental Assessment (SEA)," *Environmental Impact Assessment Review*, vol. 48, pp. 34-46, 2014, doi: 10.1016/j.eiar.2014.04.004.

- [11] J. Gao, P. Christensen, and W. Li, "Application of the WEAP model in strategic environmental assessment: Experiences from a case study in an arid/semi-arid area in China," *J Environ Manage*, vol. 198, no. Pt 1, pp. 363-371, Aug 1 2017, doi: 10.1016/j.jenvman.2017.04.068.
- [12] Secretariat of the Pacific Regional Environment Programme, "Strategic Environmental Assessment (SEA): guidelines for Pacific island countries and territories," 2020.
- [13] A. Jaeckel, "Strategic environmental planning for deep seabed mining in the area," *Marine Policy*, vol. 114, 2020, doi: 10.1016/j.marpol.2019.01.012.
- [14] R. Théritel and A. González, "Is SEA worth it? Short-term costs v. long-term benefits of strategic environmental assessment," *Environmental Impact Assessment Review*, vol. 83, p. 106411, 2020/07/01/ 2020, doi: <https://doi.org/10.1016/j.eiar.2020.106411>.
- [15] A. D. Borgaonkar and T. F. Marhaba, "Chapter 16 - Evaluation of sustainability strategies—a water quantity and quality perspective," in *Handbook of Water Purity and Quality (Second Edition)*, S. Ahuja Ed. Amsterdam: Academic Press, 2021, pp. 409-454.
- [16] H. Nautiyal and V. Goel, "Chapter 3 - Sustainability assessment: Metrics and methods," in *Methods in Sustainability Science*, J. Ren Ed.: Elsevier, 2021, pp. 27-46.
- [17] H. Zhang *et al.*, "Impacts of future climate change on water resource availability of eastern Australia: A case study of the Manning River basin," *Journal of Hydrology*, vol. 573, pp. 49-59, 2019/06/01/ 2019, doi: <https://doi.org/10.1016/j.jhydrol.2019.03.067>.
- [18] Q. Zhang, M. Gemmer, and J. Chen, "Climate changes and flood/drought risk in the Yangtze Delta, China, during the past millennium," *Quaternary International*, vol. 176-177, pp. 62-69, 2008, doi: 10.1016/j.quaint.2006.11.004.
- [19] Y. Yang, H. Xu, J. Wang, T. Liu, and H. Wang, "Integrating climate change factor into strategic environmental assessment in China," *Environmental Impact Assessment Review*, vol. 89, 2021, doi: 10.1016/j.eiar.2021.106585.
- [20] A. Iglesias and L. Garrote, "Adaptation strategies for agricultural water management under climate change in Europe," *Agricultural Water Management*, vol. 155, pp. 113-124, 2015, doi: 10.1016/j.agwat.2015.03.014.
- [21] S. Shrestha and W. Lohpaisankrit, "Flood hazard assessment under climate change scenarios in the Yang River Basin, Thailand," *International Journal of Sustainable Built Environment*, vol. 6, no. 2, pp. 285-298, 2017, doi: 10.1016/j.ijbsbe.2016.09.006.
- [22] B. Noble and K. Nwanekezie, "Conceptualizing strategic environmental assessment: Principles, approaches and research directions," *Environmental Impact Assessment Review*, vol. 62, pp. 165-173, 2017, doi: 10.1016/j.eiar.2016.03.005.
- [23] G. H. Brundtland and M. Khalid, *Our common future*. Oxford University Press, Oxford, GB, 1987.
- [24] M. d. R. Partidário, T. B. Fischer and A. González, Eds. *Handbook on Strategic Environmental Assessment: Chapter 4 Strategic thinking for sustainability (ST4S) in strategic environmental assessment*. 2021.
- [25] A. R. A. Loza and T. Fidélis, "Literature review on the analysis of climate change risks in the environmental impact assessment of dams," *Impact Assessment and Project Appraisal*, vol. 39, no. 4, pp. 277-289, 2021, doi: 10.1080/14615517.2021.1893928.
- [26] M. d. R. Partidário, "Strategic Environmental Assessment Better Practice Guide: methodological guidance for strategic thinking in SEA," [REN] Portuguese Environment Agency and Redes Energéticas Nacionais, 2012.
- [27] (2006). *Applying Strategic Environmental Assessment*.
- [28] The World Bank and The Asian Development Bank, "Climate Risk Country Profiles: Thailand," 2021.
- [29] T. Okwala, S. Shrestha, S. Ghimire, S. Mohanasundaram, and A. Datta, "Assessment of climate change impacts on water balance and hydrological extremes in Bang Pakong-Prachin Buri river basin, Thailand," *Environ Res*, vol. 186, p. 109544, Jul 2020, doi: 10.1016/j.envres.2020.109544.
- [30] Z. A. Elum, D. M. Modise, and A. Marr, "Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa," *Climate Risk Management*, vol. 16, pp. 246-257, 2017, doi: 10.1016/j.crm.2016.11.001.
- [31] S. M. Ali, B. Khalid, A. Akhter, A. Islam, and S. Adnan, "Analyzing the occurrence of floods and droughts in connection with climate change in Punjab province, Pakistan," *Natural Hazards*, vol. 103, no. 2, pp. 2533-2559, 2020, doi: 10.1007/s11069-020-04095-5.
- [32] United States Department of Agriculture, "Watershed Condition Classification Technical Guide," 2010.
- [33] D. Komori *et al.*, "Characteristics of the 2011 Chao Phraya River flood in Central Thailand," *Hydrological Research Letters*, vol. 6, no. 0, pp. 41-46, 2012, doi: 10.3178/hrl.6.41.
- [34] M. Haraguchi and U. Lall, "Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making," *International Journal of Disaster Risk Reduction*, vol. 14, pp. 256-272, 2015, doi: 10.1016/j.ijdrr.2014.09.005.
- [35] C. F. Fratini, G. D. Geldof, J. Kluck, and P. S. Mikkelsen, "Three Points Approach (3PA) for urban flood risk management: A tool to support climate change adaptation through transdisciplinarity and multifunctionality," *Urban Water Journal*, vol. 9, no. 5, pp. 317-331, 2012, doi: 10.1080/1573062x.2012.668913.
- [36] W. Bi *et al.*, "Evolution of Drought(-)Flood Abrupt Alternation and Its Impacts on Surface Water Quality from 2020 to 2050 in the Luanhe River Basin," *Int J Environ Res Public Health*, vol. 16, no. 5, Feb 26 2019, doi: 10.3390/ijerph16050691.
- [37] P. J. Posas, "Exploring climate change criteria for strategic environmental assessments," *Progress in Planning*, vol. 75, no. 3, pp. 109-154, 2011/04/01/ 2011, doi: <https://doi.org/10.1016/j.progress.2011.05.001>.
- [38] European Union, "Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment," The European Union, 2013.

- [39] M. d. R. Partidário, *Strategic Environmental Assessment Good Practices Guide*. 2007.
- [40] J. Zhang, P. Christensen, and L. Kjørnø, "Review of critical factors for SEA implementation," *Environmental Impact Assessment Review*, vol. 38, pp. 88-98, 2013, doi: 10.1016/j.eiar.2012.06.004.
- [41] D. Unalan and R. Cowell, "Strategy, context and strategic environmental assessment," *Environmental Impact Assessment Review*, vol. 79, 2019, doi: 10.1016/j.eiar.2019.106305.
- [42] National Environment Management Authority, "Guidelines for Strategic Environmental Assessment (SEA) in Uganda," 2020.
- [43] Office of the National Economic and Social Development Council, "Strategic Environmental Assessment Guideline: Thailand," 2020.
- [44] United Nations Development Programme and The REC and the Government of Georgia, "A Guide to Strategic Environmental Assessment," in "Georgian Perspective," 2006.
- [45] J. Albrecht, "Legal framework and criteria for effectively coordinating public participation under the Floods Directive and Water Framework Directive: European requirements and German transposition," *Environmental Science & Policy*, vol. 55, pp. 368-375, 2016, doi: 10.1016/j.envsci.2015.07.019.
- [46] C. Rega and G. Baldizzone, "Public participation in Strategic Environmental Assessment: A practitioners' perspective," *Environmental Impact Assessment Review*, vol. 50, pp. 105-115, 2015, doi: 10.1016/j.eiar.2014.09.007.
- [47] Y.-p. Chen *et al.*, "Sustainable development in the Yellow River Basin: Issues and strategies," *Journal of Cleaner Production*, vol. 263, 2020, doi: 10.1016/j.jclepro.2020.121223.
- [48] L. Yumagulova and I. Vertinsky, "Climate Change Adaptation and Flood Management in Metro Vancouver Regional Area: Can an Exercise in Herding Cats be Successful?," *Journal of Sustainable Development of Energy, Water and Environment Systems*, vol. 5, no. 2, pp. 273-288, 2017, doi: 10.13044/j.sdewes.d5.0149.
- [49] L. K. Caldwell, "Analysis-Assessment-Decision: The Anatomy of Rational Policymaking," *Impact Assessment*, vol. 9, no. 4, pp. 81-92, 1991, doi: 10.1080/07349165.1991.9726069.
- [50] R. Thérivel, E. Wilson, S. Thompson, D. Heaney, and D. Pritchard, *Strategic environmental assessment* (no. 1-85383-147-6). 1992.
- [51] R. Thérivel, "Systems of strategic environmental assessment," *Environmental Impact Assessment Review*, 1993.
- [52] A. L. Brown and R. Thérivel, "Principles to guide the development of strategic environmental assessment methodology," *Impact Assessment and Project Appraisal*, vol. 18, no. 3, pp. 183-189, 2000, doi: 10.3152/147154600781767385.
- [53] J. Carter and J. Howe, "The Water Framework Directive and the Strategic Environmental Assessment Directive: Exploring the linkages," *Environmental Impact Assessment Review*, vol. 26, no. 3, pp. 287-300, 2006, doi: 10.1016/j.eiar.2005.05.001.
- [54] (2006). *APPLYING STRATEGIC ENVIRONMENTAL ASSESSMENT*.
- [55] A. Donnelly, M. Jones, T. O'Mahony, and G. Byrne, "Selecting environmental indicator for use in strategic environmental assessment," *Environmental Impact Assessment Review*, vol. 27, no. 2, pp. 161-175, 2007, doi: 10.1016/j.eiar.2006.10.006.
- [56] R. Thérivel and B. Ross, "Cumulative effects assessment: Does scale matter?," *Environmental Impact Assessment Review*, vol. 27, no. 5, pp. 365-385, 2007, doi: 10.1016/j.eiar.2007.02.001.
- [57] T. Wallington, O. Bina, and W. Thissen, "Theorising strategic environmental assessment: Fresh perspectives and future challenges," *Environmental Impact Assessment Review*, vol. 27, no. 7, pp. 569-584, 2007, doi: 10.1016/j.eiar.2007.05.007.
- [58] The World Bank, "Strategic Environmental Assessment in Policy and Sector Reform," Washington DC, 2007.
- [59] O. Bina, "Strategic Environmental Assessment," in *Innovation in Environmental Policy?*, 2008, pp. 134-156.
- [60] (2009). *Integrated Water Resources joining forces for climate proofing*.
- [61] R. Thérivel, *Strategic Environmental Assessment in Action*. 2010.
- [62] M. Fundingsland Tetlow and M. Hanusch, "Strategic environmental assessment: the state of the art," *Impact Assessment and Project Appraisal*, vol. 30, no. 1, pp. 15-24, 2012, doi: 10.1080/14615517.2012.666400.
- [63] W. Wende, A. Bond, N. Bobylev, and L. Stratmann, "Climate change mitigation and adaptation in strategic environmental assessment," *Environmental Impact Assessment Review*, vol. 32, no. 1, pp. 88-93, 2012, doi: 10.1016/j.eiar.2011.04.003.
- [64] R. Thérivel and M. d. R. Partidário, *The Practice of Strategic Environmental Assessment*. the UK in 1996: Earthscan Publications Limited, 2013.
- [65] EPA, "Good Practice Guidance on Cumulative Effects Assessment in Strategic Environmental Assessment " 2020.
- [66] NEMA, "Guidelines for Strategic Environmental Assessment (SEA) in Uganda " 2020.
- [67] Office of the National Economic and Social Development Council, "Strategic Environmental Assessment Guideline, Thailand," 2020.
- [68] SPREP, "Strategic Environmental Assessment (SEA) Guidelines For Pacific Island Countries and Territories " 2020.
- [69] R. Santos Coelho, P. S. Coelho, P. Antunes, and T. B. Ramos, "Stakeholders Perspectives on the Use of Indicators in Water Resources Planning and Related Strategic Environmental Assessment," *Journal of Environmental Assessment Policy and Management*, vol. 21, no. 01, 2019, doi: 10.1142/s1464333219500017.
- [70] K. Tevapitak and A. H. J. Helmsing, "The interaction between local governments and stakeholders in

- environmental management: The case of water pollution by SMEs in Thailand," *Journal of Environmental Management*, vol. 247, pp. 840-848, 2019/10/01/2019, doi: <https://doi.org/10.1016/j.jenvman.2019.06.097>.
- [71] *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development*.
- [72] A. Polido and T. B. Ramos, "Towards effective scoping in strategic environmental assessment," *Impact Assessment and Project Appraisal*, vol. 33, no. 3, pp. 171-183, 2015, doi: 10.1080/14615517.2014.993155.
- [73] H. R. Zabr , D. Dietler, S. P. Diabougua, and M. S. Winkler, "Scoping review of the inclusion of economic analysis in impact studies of natural resource extraction projects," *Impact Assessment and Project Appraisal*, vol. 39, no. 4, pp. 304-319, 2021, doi: 10.1080/14615517.2021.1910182.
- [74] B. A. Woods, H.  . Nielsen, A. B. Pedersen, and D. Kristofersson, "Farmers' perceptions of climate change and their likely responses in Danish agriculture," *Land Use Policy*, vol. 65, pp. 109-120, 2017, doi: 10.1016/j.landusepol.2017.04.007.
- [75] D. Marks, "Climate Change and Thailand: Impact and Response," *Contemporary Southeast Asia*, vol. 33, no. 2, 2011, doi: 10.1355/cs33-2d.
- [76] Y. Y. Loo, L. Billa, and A. Singh, "Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia," *Geoscience Frontiers*, vol. 6, no. 6, pp. 817-823, 2015, doi: 10.1016/j.gsf.2014.02.009.
- [77] N. Arunrat, C. Wang, N. Pumijumngong, S. Sreenonchai, and W. Cai, "Farmers' intention and decision to adapt to climate change: A case study in the Yom and Nan basins, Phichit province of Thailand," *Journal of Cleaner Production*, vol. 143, pp. 672-685, 2017, doi: 10.1016/j.jclepro.2016.12.058.
- [78] M. B. Masud, P. Soni, S. Shrestha, and N. K. Tripathi, "Changes in Climate Extremes over North Thailand, 1960–2099," *Journal of Climatology*, vol. 2016, pp. 1-18, 2016, doi: 10.1155/2016/4289454.
- [79] L. Lebel, J. B. Manuta, and P. Garden, "Institutional traps and vulnerability to changes in climate and flood regimes in Thailand," *Regional Environmental Change*, vol. 11, no. 1, pp. 45-58, 2010, doi: 10.1007/s10113-010-0118-4.
- [80] F. Franzetti, A. Pezzoli, and M. Bagliani, "Rethinking Water Resources Management Under a Climate Change Perspective: From National to Local Level. The Case of Thailand," in *Renewing Local Planning to Face Climate Change in the Tropics*, M. Tiepolo, A. Pezzoli, and V. Tarchiani Eds. Cham: Springer International Publishing, 2017, pp. 169-195.
- [81] Royol Chitradon, Surajate Boonya-aroonnet, and Poranee Thanapakpawin, "Risk Management of Water Resources in Thailand in the Face of Climate Change," *SASIN JOURNAL OF MANAGEMENT* pp. 64-73, 2009.
- [82] S. Prabhakorn, S. Maskey, F. X. Suryadi, and C. de Fraiture, "Rice yield in response to climate trends and drought index in the Mun River Basin, Thailand," *Sci Total Environ*, vol. 621, pp. 108-119, Apr 15 2018, doi: 10.1016/j.scitotenv.2017.11.136.
- [83] Devon Hardy, Francisco Cubillo, Mooyoung Han, and H. Li, *Alternative Water Resources: A Review of Concepts, Solutions and Experiences*. [IWA] International Water Association, , 2015.
- [84] M. Meybeck, E. Kuusisto, A. M kel , and M. E., J. Bartram and R. Ballance, Eds. *Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes*. United Nations Environment Programme and the World Health Organization, 1996.
- [85] Office of Research Development and Hydrology Department of Water Resources, *Standards for the classification of major and regional river basins in Thailand*. 2009.
- [86] Stephen W. Lipscomb, *Hydrologic Classification and Estimation of Basin and Hydrologic Characteristics of Subbasins in Central Idaho*. U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1604: BUREAU OF INDIAN AFFAIRS, 1998.
- [87] The World Bank, "Thailand environment monitor: Integrated Water Resources Management: A Way Forward," Disclosure Authorized, , 2011.
- [88] B. Ekasingh and K. Ngamsomsuke, "Searching for simplified farmers' crop choice models for integrated watershed management in Thailand: A data mining approach," *Environmental Modelling & Software*, vol. 24, no. 12, pp. 1373-1380, 2009, doi: 10.1016/j.envsoft.2009.02.015.
- [89] S. Tsani, P. Koundouri, and E. Akinsete, "Resource management and sustainable development: A review of the European water policies in accordance with the United Nations' Sustainable Development Goals," *Environmental Science & Policy*, vol. 114, pp. 570-579, 2020, doi: 10.1016/j.envsci.2020.09.008.
- [90] J. Alcamo, M. Fl rke, and M. M rker, "Future long-term changes in global water resources driven by socio-economic and climatic changes," *Hydrological Sciences Journal*, vol. 52, no. 2, pp. 247-275, 2007, doi: 10.1623/hysj.52.2.247.
- [91] Z. W. Kundzewicz, "Water resources for sustainable development," *Hydrological Sciences Journal*, vol. 42, no. 4, pp. 467-480, 1997, doi: 10.1080/02626669709492047.
- [92] S. Boonwichai, S. Shrestha, M. S. Babel, S. Weesakul, and A. Datta, "Climate change impacts on irrigation water requirement, crop water productivity and rice yield in the Songkhram River Basin, Thailand," *Journal of Cleaner Production*, vol. 198, pp. 1157-1164, 2018, doi: 10.1016/j.jclepro.2018.07.146.
- [93] Y. Zhang *et al.*, "A framework estimating cumulative impact of damming on downstream water availability," *Journal of Hydrology*, vol. 575, pp. 612-627, 2019, doi: 10.1016/j.jhydrol.2019.05.061.
- [94] Z. Jia, Y. Cai, Y. Chen, and W. Zeng, "Regionalization of water environmental carrying capacity for supporting the sustainable water resources management and development in China," *Resources, Conservation and Recycling*, vol.

- 134, pp. 282-293, 2018, doi: 10.1016/j.resconrec.2018.03.030.
- [95] E. Petelet-Giraud *et al.*, "Multi-layered water resources, management, and uses under the impacts of global changes in a southern coastal metropolis: When will it be already too late? Crossed analysis in Recife, NE Brazil," *Sci Total Environ*, vol. 618, pp. 645-657, Mar 15 2018, doi: 10.1016/j.scitotenv.2017.07.228.
- [96] A. Di Vaio, L. Trujillo, G. D'Amore, and R. Palladino, "Water governance models for meeting sustainable development Goals: A structured literature review," *Utilities Policy*, vol. 72, 2021, doi: 10.1016/j.jup.2021.101255.
- [97] F. Vanclay, "International Principles For Social Impact Assessment," *Impact Assessment and Project Appraisal*, vol. 21, no. 1, pp. 5-12, 2003, doi: 10.3152/147154603781766491.
- [98] C. Allan, "Can adaptive management help us embrace the Murray-Darling Basin's wicked problems?," in *Adaptive and Integrated Water Management*, 2008, ch. Chapter 4, pp. 61-73.
- [99] U. Baresi, K. J. Vella, and N. G. Sipe, "A limits-oriented adaptive approach for strategic environmental assessment," *Environmental Science & Policy*, vol. 114, pp. 128-139, 2020/12/01/ 2020, doi: <https://doi.org/10.1016/j.envsci.2020.07.031>.
- [100] S. Pak-Uthai and N. Faysse, "The risk of second-best adaptive measures: Farmers facing drought in Thailand," *International Journal of Disaster Risk Reduction*, vol. 28, pp. 711-719, 2018/06/01/ 2018, doi: <https://doi.org/10.1016/j.ijdr.2018.01.032>.
- [101] International Finance Corporation, "Baselines Assessment report on social and livelihoods Strategic Environmental Assessment of the Hydropower Sector in Myanmar," 2017.
- [102] M. Cinelli, S. R. Coles, and K. Kirwan, "Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment," *Ecological Indicators*, vol. 46, pp. 138-148, 2014, doi: 10.1016/j.ecolind.2014.06.011.
- [103] I. Coteur, H. Wustenberghs, L. Debruyne, L. Lauwers, and F. Marchand, "How do current sustainability assessment tools support farmers' strategic decision making?," *Ecological Indicators*, vol. 114, p. 106298, 2020/07/01/ 2020, doi: <https://doi.org/10.1016/j.ecolind.2020.106298>.
- [104] I. Coteur, H. Wustenberghs, L. Debruyne, L. Lauwers, and F. Marchand, "How do current sustainability assessment tools support farmers' strategic decision making?," *Ecological Indicators*, vol. 114, 2020, doi: 10.1016/j.ecolind.2020.106298.
- [105] S. Bid and G. Siddique, "Human risk assessment of Panchet Dam in India using TOPSIS and WASPAS Multi-Criteria Decision-Making (MCDM) methods," *Heliyon*, vol. 5, no. 6, p. e01956, Jun 2019, doi: 10.1016/j.heliyon.2019.e01956.
- [106] D. Kellon and J. Arvai, "Five propositions for improving decision making about the environment in developing communities: insights from the decision sciences," *J Environ Manage*, vol. 92, no. 3, pp. 363-71, Mar 2011, doi: 10.1016/j.jenvman.2010.10.010.
- [107] D. Kellon and J. Arvai, "Five propositions for improving decision making about the environment in developing communities: Insights from the decision sciences," *Journal of Environmental Management*, vol. 92, no. 3, pp. 363-371, 2011/03/01/ 2011, doi: <https://doi.org/10.1016/j.jenvman.2010.10.010>.
- [108] M. Wood, "The Pros and Cons of Using Pros and Cons for Multi-Criteria Evaluation and Decision Making," *SSRN Electronic Journal*, 2009, doi: 10.2139/ssrn.1545189.
- [109] E. Szimbaa, B. Mandelb, M. Krafta, and I. J., "A Decision Support Tool for the Strategic Assessme," *transportation Research Procedia*, 2017.
- [110] D. R. Purkey, A. Huber-Lee, D. N. Yates, M. Hanemann, and S. Herrod-Julius, "Integrating a Climate Change Assessment Tool into Stakeholder-Driven Water Management Decision-Making Processes in California," *Water Resources Management*, vol. 21, no. 1, pp. 315-329, 2006, doi: 10.1007/s11269-006-9055-x.
- [111] The Environmental Protection Agency, "Good Practice Guidance on Cumulative Effects Assessment in Strategic Environmental Assessment," 2020.
- [112] (2002). *World Development Report*.
- [113] The World Bank, *Strategic Environmental Assessment in Policy and Sector Reform*. 2007.
- [114] P. Willems, K. Arnbjerg-Nielsen, J. Olsson, and V. T. V. Nguyen, "Climate change impact assessment on urban rainfall extremes and urban drainage: Methods and shortcomings," *Atmospheric Research*, vol. 103, pp. 106-118, 2012, doi: 10.1016/j.atmosres.2011.04.003.
- [115] C. Tapia *et al.*, "Profiling urban vulnerabilities to climate change: An indicator-based vulnerability assessment for European cities," *Ecological Indicators*, vol. 78, pp. 142-155, 2017, doi: 10.1016/j.ecolind.2017.02.040.
- [116] B. Ye, J. Jiang, J. Liu, Y. Zheng, and N. Zhou, "Research on quantitative assessment of climate change risk at an urban scale: Review of recent progress and outlook of future direction," *Renewable and Sustainable Energy Reviews*, vol. 135, 2021, doi: 10.1016/j.rser.2020.110415.
- [117] K. Abbass, M. Z. Qasim, H. Song, M. Murshed, H. Mahmood, and I. Younis, "A review of the global climate change impacts adaptation and sustainable mitigation measures," *Environ Sci Pollut Res Int*, vol. 29, no. 28, pp. 42539-42559, Jun 2022, doi: 10.1007/s11356-022-19718-6.
- [118] E. Duku, P. A. Dzorgbe Mattah, and D. B. Angnuureng, "Assessment of wetland ecosystem services and human wellbeing nexus in sub-Saharan Africa: Empirical evidence from a socio-ecological landscape of Ghana," *Environmental and Sustainability Indicators*, vol. 15, 2022, doi: 10.1016/j.indic.2022.100186.
- [119] H. t. Stack, "Layer 8: The People Layer," in *Hack the Stack*, 2006, ch. Chapter 9 pp. 353-400.
- [120] D. Iakovidis, Y. Gadanakis, and J. Park, "Farm-level sustainability assessment in Mediterranean environments: Enhancing decision-making to improve business sustainability," *Environmental and Sustainability Indicators*, vol. 15, 2022, doi: 10.1016/j.indic.2022.100187.

- [121] D. Anghileri, F. Pianosi, and R. Soncini-Sessa, "A framework for the quantitative assessment of climate change impacts on water-related activities at the basin scale," *hydrology and Earth System Sciences Discussions*, 2011, doi: 10.5194/hessd-8-585-2011.
- [122] M. Dou, J.-x. Ma, G.-q. Li, and Q.-t. Zuo, "Measurement and assessment of water resources carrying capacity in Henan Province, China," *Water Science and Engineering*, vol. 8, no. 2, pp. 102-113, 2015, doi: 10.1016/j.wse.2015.04.007.
- [123] L. T. Bui and H. T. H. Pham, "Linking hydrological, hydraulic and water quality models for river water environmental capacity assessment," *Science of The Total Environment*, vol. 857, p. 159490, 2023/01/20/ 2023, doi: <https://doi.org/10.1016/j.scitotenv.2022.159490>.
- [124] E. U. F Firmansyah, M Yusuf, and N A Pratomoatmojo, "Carrying capacity and environmental capacity analysis based on ecosystem services in Surabaya," *Earth and Environmental Science*, 2020, doi: 10.1088/1755-1315/562/1/012027.
- [125] D. Marganingrum, "Carrying capacity of water resources in Bandung Basin," *Global Colloquium on GeoSciences and Engineering*, 2017.
- [126] L. Guo, W. Zhu, J. Wei, and L. Wang, "Water demand forecasting and countermeasures across the Yellow River basin: Analysis from the perspective of water resources carrying capacity," *Journal of Hydrology: Regional Studies*, vol. 42, 2022, doi: 10.1016/j.ejrh.2022.101148.
- [127] P. Tsangaratos, I. Ilija, and I. Matiatos, "1 - Spatial Analysis of Extreme Rainfall Values Based on Support Vector Machines Optimized by Genetic Algorithms: The Case of Alfeios Basin, Greece," in *Spatial Modeling in GIS and R for Earth and Environmental Sciences*, H. R. Pourghasemi and C. Gokceoglu Eds.: Elsevier, 2019, pp. 1-19.
- [128] Y. Liu *et al.*, "Quantitative analysis of climate change impact on Zhangye City's economy based on the perspective of surface runoff," *Ecological Indicators*, vol. 105, pp. 645-654, 2019, doi: 10.1016/j.ecolind.2018.06.059.
- [129] D. Xue *et al.*, "Impacts of climate change and human activities on runoff change in a typical arid watershed, NW China," *Ecological Indicators*, vol. 121, 2021, doi: 10.1016/j.ecolind.2020.107013.
- [130] A. A. Fenta, H. Yasuda, K. Shimizu, and N. Haregeweyn, "Response of streamflow to climate variability and changes in human activities in the semiarid highlands of northern Ethiopia," *Regional Environmental Change*, vol. 17, no. 4, pp. 1229-1240, 2017, doi: 10.1007/s10113-017-1103-y.
- [131] OECD., "Assessing the impact of climate change on water supply sources and WSS systems in Moldova and inventory possible adaptation measures (Task 1)," European Union and co-sponsored by the OECD EAP Task Force., 2013.
- [132] P. Dahal, M. L. Shrestha, J. Panthi, and D. Pradhananga, "Modeling the future impacts of climate change on water availability in the Karnali River Basin of Nepal Himalaya," *Environmental Research*, vol. 185, p. 109430, 2020/06/01/ 2020, doi: <https://doi.org/10.1016/j.envres.2020.109430>.
- [133] E. Bhardwaj and P. A. Khaiteer, "What data analytics can or cannot do for climate change studies: An inventory of interactive visual tools," *Ecological Informatics*, vol. 73, 2023, doi: 10.1016/j.ecoinf.2022.101918.
- [134] K. A. Yeboah *et al.*, "Assessing climate change projections in the Volta Basin using the CORDEX-Africa climate simulations and statistical bias-correction," *Environmental Challenges*, vol. 6, 2022, doi: 10.1016/j.envc.2021.100439.
- [135] G. M. Munna, M. J. B. Alam, M. M. Uddin, N. Islam, A. A. Orthee, and K. Hasan, "Runoff prediction of Surma basin by curve number (CN) method using ARC-GIS and HEC-RAS," *Environmental and Sustainability Indicators*, vol. 11, 2021, doi: 10.1016/j.indic.2021.100129.
- [136] D. A. Malede, T. Alamirew, J. R. Kosgie, and T. G. Andualem, "Analysis of land use/land cover change trends over Birr River Watershed, Abbay Basin, Ethiopia," *Environmental and Sustainability Indicators*, vol. 17, 2023, doi: 10.1016/j.indic.2022.100222.
- [137] B. E. Taiwo *et al.*, "Monitoring and predicting the influences of land use/land cover change on cropland characteristics and drought severity using remote sensing techniques," *Environmental and Sustainability Indicators*, 2023, doi: 10.1016/j.indic.2023.100248.
- [138] R. C. Sandrine Bony, Thierry Fichet, John Fyfe, Vladimir Kattsov, Andrew Pitman, Jagadish Shukla, Jayaraman Srinivasan, Ronald J. Stouffer, Akimasa Sumi, Karl E. Taylor, "Climate Models and Their Evaluation," The Intergovernmental Panel on Climate Change (IPCC), 2007.
- [139] W. C. Somphiphith Muangthong, Kanoksri Sarinnapakorn, and Khanittha Chaibandit, "Prediction of Future Drought in Thailand under Changing Climate by Using SPI and SPEI Indices," 2020.
- [140] C. Qi and N.-B. Chang, "Integrated carbon footprint and cost evaluation of a drinking water infrastructure system for screening expansion alternatives," *Journal of Cleaner Production*, vol. 27, pp. 51-63, 2012/05/01/ 2012, doi: <https://doi.org/10.1016/j.jclepro.2012.01.009>.
- [141] B. Ness, E. Urbel-Piirsalu, S. Anderberg, and L. Olsson, "Categorising tools for sustainability assessment," *Ecological Economics*, vol. 60, no. 3, pp. 498-508, 2007, doi: 10.1016/j.ecolecon.2006.07.023.
- [142] Z. Tang, "Integrating the principles of strategic environmental assessment into local comprehensive land use plans in California," Ph.D., Texas A&M University, Ann Arbor, 3270400, 2007. [Online]. Available: <https://search.proquest.com/dissertations-theses/integrating-principles-strategic-environmental/docview/304729269/se-2?accountid=48250>
- [143] R. Santos Coelho, R. Lopes, P. S. Coelho, T. B. Ramos, and P. Antunes, "Participatory selection of indicators for water resources planning and strategic environmental assessment in Portugal," *Environmental Impact Assessment Review*, vol. 92, 2022, doi: 10.1016/j.eiar.2021.106701.

Biographies



Warangluck Na sorn She received her B.Sc. (Environmental Science) in 2011 and M.Eng. (Environmental Engineering) from Chulalongkorn University in 2014. She is currently (in 2023) an environmentalist at the Royal Irrigation Department, Thailand and a Ph.D. candidate at the Department of Environmental Engineering, Kasetsart University.



Sanya Sirivithayapakorn He earned his B.Sc. (Marine Science) from Chulalongkorn University in 1994, his M.Sc. (Environmental Science and Engineering) from the University of Texas, Arlington, USA in 1998, and his Ph.D. (Environmental Science and Management) from the University of California, Santa Barbara, USA in 2003. He is currently Associate Professor at the Department of Environmental Engineering, Kasetsart University, Thailand.



Sucheela Polruang She earned her Dipl.-Ing. in Mechanical Engineering from RWTH Aachen University in 2010 and her Ph.D. from the Faculty of Engineering, Kasetsart University in Thailand in 2018. She is currently an Assistant Professor at the Department of Environmental Engineering, Kasetsart University in Thailand.



Narumol Vongthanasunthorn She earned her B.E. from Kasetsart University, Thailand in 1998, her M.E. from Saga University, JAPAN in 2000, and her D.E. from Saga University, JAPAN in 2004. Currently, she is an Associate Professor at the Faculty of Science and Engineering, Department of Civil Engineering and Architecture