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Review of The Tools and Techniques Used in Risk Based Land Use Planning: An Innovative Participatory/GIS based Approach for Mauritius

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Abstract

Land use planning can now be considered as one of the best practices within natural Disaster Risk Management to improve the resilience of communities, ensure the safety of people and increase sustainability. Yet traditional land use planning and management practices lack the systematic nature to deal with risks associated with hazards, exposure and vulnerability. Risk based land use planning provides planners and managers the opportunity to move beyond planning for the likelihood of a natural hazard and to plan for the consequences of an event. The aim of this study was to review the tools and techniques that are used in risk based land use planning and eventually select a suitable one for the present case study, Mauritius. Google scholar was used as portal and keywords such as "risk based land use planning" were entered to extract relevant publications for the period 2010 to 2020. Over 90 papers were reviewed and 15 tools and techniques were identified as being in use in risk based land use planning. Consequently, an innovative 7-steps participatory/GIS based approach for risk reduction in the Mauritian context was proposed which considers communities' participation in mapping land uses and disasters and translating the information onto GIS maps for visualization.

Keywords: Risk based land use planning; land use planning; risk management; Mauritius.

1. Introduction

Reference [1] states that for hundreds of years, humans have lived with the reality and the threat of natural hazards impacting on their belongings and lives.

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The urban population alone is expected to reach 5 billion by 2030, increasing risk associated with the large number of people living and infrastructure built in exposed places [2]. As risk rises globally, the global community continues to explore ways to reduce disaster events. Land use planning's role is now pivotal in creating safer communities and increasing sustainability with the aim to reduce risks to disasters throughout all the stages of disaster planning. In this respect, Reference [3] further urge that land use planning must now be actively considered as a procedure for pre-disaster, preparedness, prevention and mitigation for disasters, in the organization of recovery plans, in the coordination of recovery operations, during displacement of populations and reconstruction phases. Land use planning can now be considered as one of the best practices within natural Disaster Risk Management to improve the resilience of communities, ensure the safety of the people and increase sustainability [3]. Yet traditional land use planning and management practices lack the systematic nature to deal with the sustainability issues that today's society has to deal with [4]. By considering the risks associated with hazards, exposure and vulnerability, communities can consider the spatial distribution of disaster risks during their planning phases and thus gear towards sustainable land development and thus significantly reduce their vulnerability, especially that of the poor populations which are often settled on the degraded sites [3]. Risk based land use planning provides planners and managers the opportunity to move beyond planning for the likelihood of a natural hazard and to plan for the consequences of an event [5]. If land use planning is planned on the systematic assessment of risk assessment, applied assiduously, and monitored on a continuous basis, it can greatly diminish existing, residual and future risks. In order to decrease disaster risks and adapt to climate change, good practices in land use planning both at the local and regional levels have now become vital [6]. Identified as a need during the IDNDR and as a priority action by the Hyogo Framework for Action, it is now the responsibility of planners and decision makers to actively engage in risk based land use planning processes and mechanisms. Right now, the Earth's population is already causing extensive modifications in land use and the spatial patterns of land cover [7]. Climate patterns are now changing drastically and becoming highly variable challenging responsible institution's and regulating bodies' regulations on land use planning. Events like flooding, storm surges, bushfires and landslides can have serious consequences on the environment, economy and society at large. The dreadful effects of slow onset hazards like drought can have secondary impacts on planning in the form of relocation, decommissioning or abandonment of settlements and more long term land use changes [6]. Reference [8] propound that given the urgency that climate change impacts present, it is essential to link disaster management, climate change and land use planning as part of a wholesome package in order to decrease disaster risks in a holistic manner. Risk management is in fact a crucial step in risk reduction and based on the use of land and the application of technical and scientific inputs during the planning process using various tools and techniques for rational risk based land use planning. Nonetheless, risk based land use planning is a relatively new topic with very few published content. In this respect, the aim of this study was to review the tools and techniques that are in use worldwide for risk based land use planning and assess the pros and cons of each tool so as to select a suitable one for the present case study, Mauritius.

2. Materials and Methods

Secondary data analysis was used to carry out this study as it provides details and in-depth information about this topic and includes individual experiences in different countries. A thorough search was conducted on Google Scholar from 2010 to 2020, sorted by relevance as it is a free, accessible web engine that indexes the full

text of scholarly publications across a range of publishing formats and disciplines [9]. A period of ten years was chosen to obtain a comprehensive and accurate collection of publications on the topic so as to support the meta-scientific findings. Thus, to retrieve the required publications, a search query was initiated using the following keywords: "tools and techniques for risk based land use planning", "risk based land use planning", "tools for risk based land use planning" AND "disaster risk management", "land use planning" AND "risk based" in the Google Scholar search bar. An advanced search in the Google Scholar database was also conducted for the years 2010 to 2020 using the same keywords "risk based land use planning", "tools and techniques for risk based land use planning", "land use planning" AND "disaster risk management", "tools for risk based land use planning", "land use planning" AND "risk based" in the title of the article search bar. For this study, data reliability was tested according to the sources of the scientific journals and reports used. Data validity was measured by the accuracy of the papers related to the topic and adequate content coverage and was also assessed by face validity through an evaluation of the papers and on the researcher's expertise and familiarity with the topic. However, there were a few limitations in the study that required the need to make appropriate decisions. Firstly, risk based land use planning is a relatively new topic with limited information on the matter, so searches were mostly focused on general land use planning and disaster risk management. Secondly, there is no available data per se on risk based land use planning for island nations like Mauritius. Thus, the proposed framework is based on available information on risk based risk land use planning from larger countries and applied in the local context.

3. Results

3.1. Identified risk based land use planning tools and techniques

Based on the above mentioned criteria, 90 papers were selected as relevant to the present study and 15 tools and techniques were identified as being in use in risk based land use planning. The 15 risk based land use planning tools identified, their definition, purpose, application, advantages and disadvantages are summarized in Table 1.

Table 1: Summary of risk based land use planning tools

ID	Tool/Technique	Definition	Purpose	Application	Advantages	Disadvantages
1	Acts	An act is a statutory plan passed by Congress or any legislative body in the form of a 'bill' until it is enacted and becomes a law.	Land use planning acts ensure that development is carried out in the intended way and sanctions are taken if not.	United States, Europe, Haiti, Mauritius	- Best and most reliable source of law for land use planning - Statutory law is rigid and applicable to all development	- Certain laws may abridge the rights of individuals
2	Regulations	Prescribed by a superior or competent authority, a regulation is a rule of order having the force	Regulations on land use planning are set to achieve developmental safety, environmental	Australia, Singapore, Holland, Mauritius	- Decrease disaster risks - Provide positive health outcomes	- Land use planning regulations affect the housing market with repercussions

		of law that relates to the actions of those under the authority's control.	preservation and for aesthetic purposes.			on social welfare
3	Policies	A policy refers to the general principles by which a government is guided in its management of public affairs, or the legislature in its measures.	Lan use planning policies provide the framework for authorities to plan, shape and control the use of land within an area.	United States, Australia, Maldives, Mauritius	- Provide a framework for consistent decision making and action - Define the rules and procedures that apply to all development projects	- Land use planning policies can restrict innovation and flexibility - Too many policies can become cumbersome
4	Guidelines	A guideline is a statement or other indication of policy or procedure by which to determine a course of action.	The guidelines in land use planning describe the nature, purpose and activities involved in the management, conservation and development of land.	Japan, Zimbabwe, Holland Singapore, Mauritius	- Clearly laid out steps make it easier to understand development	- Guidelines limit personal land development
5	Coordination	Coordination is the harmonious functioning of all the other functions of management.	Coordination in land use planning ensures the smooth interplay of management functions so as to decrease time, efforts and money among different authorities sharing the same jurisdictions over a delimited territory.	United Kingdom, Canada, Uganda. Madagascar	- Good coordination decreases the impacts of disasters as number of deaths	- Poor coordination increases disaster severity
6	Risk assessment	A systematic process of evaluating the potential risks that may be involved in a projected activity or undertaking.	Risk assessment in land use planning ensures safety of development and decreases hazards' impacts on communities.	Australia, Canada, India	- Identifies risks at an early stage and aim to decrease impacts	- Depends also on external entities no matter how much planning is made
7	Strategic Environmental Assessment	SEA is a process and a tool for evaluating the effects of proposed policies, plans and programmes on natural resources, social, cultural and economic	SEA addresses the pressures on the poor, the physical environment, institutional factors within the three sustainability dimensions.	UK, America, Japan	- Takes a broad view on the social, economic and environmental dimensions of sustainability	- Can be difficult to conduct as it considers a large area and requires a large amount of data

		conditions and the institutional environment in which decisions are made.				
8	Cost benefit analysis	Cost-benefit analysis is a technique used to compare the total costs of a project with its benefits, using a common metric (most commonly monetary units) so as to calculate the net benefit or cost associated with the project.	The purpose of cost benefit analysis in land use planning is to have a systematic approach to understand the positives and negatives of different paths including transactions, tasks, requirements and investments.	Canada, Europe, Australia	- Higher sale rates - Increases security for buyers	- Does not take into account all variables
9	Insurance	Insurance is an arrangement usually in the form of a policy in which a person or entity receives compensation for a covered loss.	The purpose of insurance in land use planning is to reduce projects' exposure to the effects of particular risks.	United Kingdom, Belgium, Australia, Jamaica	- Ensures monetary gains for post-disaster rebuilding	- Process can be lengthy
10	Compensation	Compensation is typically money that is awarded to someone in recognition of loss, suffering or injury.	Compensation in land use planning ensures monetary gains to people for developmental reasons or for losses.	United States, Australia, Dominica	- Helps to mitigate disaster risk	- There may be disagreement on legally binding policies concerning the terms and conditions
11	Zoning	Zoning is dividing or assigning land into zones.	The main purpose of zoning is to segregate land uses deemed incompatible.	United States, Japan, Australia, Canada	- Can conserve and enhance property values - Can prevent mixing of incompatible land use	- Can increase the cost of building infrastructure - Can discourage development in certain areas
12	Building codes	A code is a set of rules or principles or laws (especially written ones).	Building codes are regulations that shape buildings, infrastructure.	Japan, United Kingdom, Caribbean Islands, Mauritius	- Safety is the primary purpose - Decreases disaster risks	- Expensive - Shortage of skills
13	Modeling tools	Mathematical equations or computer based software such as GIS, visual analysis, audit trails or sensitivity analyses.	Modeling tools are used to understand and model disasters during the planning process.	USA, Europe, New Zealand, New Guinea	- Highly effective - Permit visualization of real situation beforehand	- Can be expensive - Technical expertise required

14	Master plan	It is a comprehensive document on land development policy and general allocation of land of a region, country or local community.	It serves the purpose of expressing political preferences for land administration and translating and adapting national policies to local and regional regulations for land development and regulated spatial planning.	Australia, Canada, New Zealand	- Tangible statements that bring together the concerns of different interest groups - Involves communities and stakeholders	- Expensive - Sometimes may not be applied at all
15	Public partici pation	Public participation can be described as a deliberative process by which interested or affected citizens, civil society organizations, and government actors are involved in policy-making before a political decision is taken.	The main purpose of public participation is to encourage the public to have meaningful input into the decision making process.	New Zealand, Canada, Australia	- Involves community so strengthens community resilience - Community more willing to cooperate with authorities during disaster management	- Can be time consuming - Expensive

3.2. Creative Use of Methods

Besides the above mentioned risk based land use planning tools and techniques, [10] declare that it exists a wide variety of tools and techniques which have their own justification and usefulness based on the situation. Tailor made tools for the state of Florida in the United States may not be applicable to the island of Mauritius and vice versa. As such, many alternative tools are developed locally and used with varying degrees of success. Responses to different land use practices must be found in a creative way depending on the needs, availability of data, appropriate methods used to collect data and credibility of such data.

4. Discussion

4.1. Risk based land use planning tools and techniques

While fifteen risk based land use planning tools have been identified in Table 1, we categorize them into six main groups:

1. Legislative tools including Acts, Regulations, Policies, Guidelines
2. Organizational and administrative tools including Coordination, Risk Assessment, Strategic Environmental Assessment
3. Economic tools including Cost Benefit analysis, Insurance, Compensation

4. Engineering and technical tools including Zoning, Building codes
5. Modeling and Technological tools
6. Monitoring and informative tools including Masterplan, Public Participation

4.1.1. Legislative tools

Typically, risk based land use planning tools enable the relevant people, institutions and groups to actively participate in the process of risk based land use planning and are crucial for collecting and analyzing information. In fact, land use planning is an important policy area that helps in the development of environmental, social and economic goals. Legislative tools such acts, regulations, policies and guidelines in land use planning guide and restrict how land should be used. Moreover, tax policies can also provide incentives to guide land use by encouraging compact development in certain regions and thus prevent urban sprawl. Basically, it is the task of national governments to decide on the incentives when designing their fiscal and land use planning systems.

4.1.2. Organizational and administrative tools

Organizational and administrative tools for risk based land use planning relate to coordination between authorities, risk assessment and strategic environmental assessment. As a comprehensive approach, land use planning raises important issues in relation to coordination among different authorities sharing the same jurisdictions over a delimited territory. In the context of a natural disaster emergency, poor coordination between the different involved authorities can even increase the magnitude or severity of the disaster [3]. It is crucial that ways of inter-institutional collaboration and logical responsibility sharing processes be managed effectively among different government entities, and different levels of authority (local, metropolitan, regional, national), diverging orientations, resources, budgets and agendas. The land use planning mandate generally depends on departments that operate in different ministries other than the disaster risk management authority and there can be little coordination due to jealousy and mutual ignorance with regards to interest. Importance must also be attached to indigenous communities and their local customary tenure systems and decision-making processes. Also, in the disaster risk management context, integration of gender dimensions in all phases from preparedness to reconstruction is very important as land policies are about equity [3]. Likewise, risk assessment plays a key role in risk based land use planning to identify constraints and contingencies for particular zones and locations. For instance, regarding landslides, buildings construction could be limited to one storey while industrial processes should be forbidden. Similarly, Strategic Environmental Assessment (SEA) in land use decision making is an important tool for future spatial planning. Understanding landscape dynamics helps in the planning and management of natural resources in particular regions. SEAs help in evaluating the effects of proposed plans on the three dimensions of sustainability and identify subsequent pressures on the physical environment.

4.1.3. Economic tools

In order to build resilience and establish policies and structures to decrease disaster risk, finance is required.

Cities especially which drive the economic sector because of their assets and high density of people also make these places quite vulnerable to disasters. It takes a significant amount of funds to protect cities and decrease damages and loss of lives. Worldwide, the need for urban infrastructure is $4.5 trillion annually, and will take a premium of 9-27% to make it climate resilient. Funding comes through public, private and philanthropic sources and multilateral development banks like the World Bank. Feasibility of insurance and monetary compensation to exposed population is thus required. In fact, insurance, where the premium cost for insured is associated with exposure to risk, may be complementary to avoid disasters.

4.1.4. Engineering and technical tools

When it comes to engineering and technical tools, zoning and building codes have proved their efficiency over the years. Zoning is in fact one of the oldest and fundamental tools that local governments use to regulate land use over time. A zoning map divides the land area within a government's jurisdiction into different districts and a zoning ordinance establishes regulations applicable within those districts. Zoning ordinances regulate permitted land uses, development density and intensity, placement and dimensions of particular uses, parking and related development issues. The effective use of zoning can help communities protect valuable natural resources like open space and agricultural land by categorizing the land for specific uses based on what is allowed or not. Zoning regulations work best when they are regularly updated and consistent with local plans. As for building codes, the resiliency of such practices can be clearly seen in developed countries like Japan to resist earthquakes. By establishing standards and implementing mechanisms for inspection of new constructions, a solid institutional and technical foundation from which to address the significant disaster risk of existing vulnerable settlements can be provided.

4.1.5. Modeling and Technological Tools

A key tool in risk based land use planning is modeling which can be in the form of mathematical equation or computer based software such as GIS, visual analysis, audit trails or sensitivity analyses. Disasters, which are predicted to increase in frequency and intensity in the coming years due to climate change, are cross scale in their impacts, disrupting multi-level functioning of socio-cultural systems. Governments need policies to support community preparedness and recovery from disasters and consequently they have to understand and model disaster resilience as accurately as possible. These disasters can be rapid or slow onset events, requiring different responses to facilitate resilience be it at the community or individual level. By compiling baseline data describing each community's characteristics and potential vulnerabilities, governments can target preparedness strategies where they are the most effective. Moreover, geospatial information from remote sensing techniques and aerial imagery, now forms a fundamental part of risk based land use planning. These tools can have several objectives in planning such as reducing nuisance sources like dust and heat, avoiding conflicts with other land uses, identifying land development objectives on the short, mid and long terms, maintain land value by prohibiting conflicting uses, reduce disaster impacts by risk assessment and risk mapping and imposing legal restrictions on land uses.

4.1.6. Monitoring and informative tools

These tools include mainly masterplans and public participation. As it is, with a masterplan, many land related issues can be addressed such as agricultural production, food security, watershed management, informal settlements, desertification, urban sprawl, natural disaster vulnerability to name a few. The master plan can state the relevancy of some sites for some particular uses based on the political decision making process but it cannot be enforced against people living in vulnerable areas without a well-developed, mid-term relocation plan. Often, land use planning decisions are hindered due to limiting factors like coastal erosion, seismic risk and contaminated ground; opportunities and preferences are also not totally independent and free of preferences. While land use planning provides a sense of duty by taking into account the very nature of these limiting factors and their impacts on land use, the master plan expresses both the preferences and the contingencies and illustrates the outline of spatial organization like infrastructures and areas vulnerable to disasters. As for public participation, it seeks the support of the communities that are going to be affected by the land use decisions. It is an important tool in risk based land use planning as it gives insight into the transparency, legitimacy and social acceptance of disaster risk reduction planning such as relocation, resettlement plans and preventive actions [3]. Also, by including the public in disaster planning, it strengthens individual and community resilience to react safely in emergency situations and to comply with respective authorities during recovery actions. Public participation works well during the preparedness phase of disaster management as during other stages where it might propel decision makers into quick, not well thought-through decisions.

4.2. Mainstreaming disaster risk reduction into land use planning

Typically, people choose to settle in locations exposed to natural hazards as they perceive the risk associated with these hazards less compared to the benefits they anticipate. As an example, people may opt to live on a floodplain because of the fertile soils and proximity to water notwithstanding occasional flooding. Conversely, people may inhabit risk prone areas such as slums and squatter settlements out of need. Though natural hazards may not always be catastrophic, when these events go beyond the coping capacity of the communities and impact on their resources and lives, they are considered as disasters [1]. It is now well established that disaster risk does not only consider the physical characteristics of natural hazard events such as the magnitude, recurrence interval, direction etc. but also takes into consideration the products of these events and the vulnerability of the community, including socio-economic drivers, and their ability to cope with such events. Yet, despite much research being conducted on the topic and extensive international efforts to reduce risks associated with natural hazards and build resilience, the global impacts of natural hazards continue to rise, with the poor and marginalized nations the most affected. Every year natural disasters such as earthquakes, landslides, hurricanes amongst others, result in 90,000 deaths and affect some 160 million people on the planet. [1] further asserts that the vulnerability of people to natural hazards are increasing as a result of population growth, human modification of natural systems thus reducing their protective abilities, urbanization of rural and coastal regions, intensification of people in megacities as well as underlying socio-political drivers. Today, these matters are made even worse with climate change which will only exacerbate disaster risk. The role of land use planning was reinforced in the Hyogo Framework of Action for the years 2005 to 2015 following the Yokohama Strategy and the international decade for natural disaster reduction [11]. Nonetheless, a mid-term review of the Hyogo Framework of action showed that little progress had been made with adequate risk assessments completed by only a few countries in 2007 [12]. It was reported that reducing underlying risks made little

progress mainly because of ongoing rapid urbanization, climate change and poverty induced vulnerability. Yet despite the challenges, many governments recognize the need to mainstream disaster risk reduction across all sectors thus identifying land use planning as a pivotal tool to decrease future risks.

4.3. Importance of risk based land use planning tools and techniques

As [2] state, encouraging risk based land use planning plays a key role in decreasing risks associated with land use especially since disaster risk reduction is still majorly based on post disaster and civil construction measures rather than emphasizing on preventive practices through long term investments in disaster risk reduction and spatial planning. Typically, risk based land use planning has a number of applications, from urban agriculture planning in the United States (e.g. [13]) to coastal planning in Tasmania (e.g. [14]). [15] state that the damage caused by natural hazards has risen steadily in recent decades, despite considerable expenditure on defenses. This is mostly due to an ever denser and more intensive use of space, and the extension of land usage to hazard areas. A change of perspective is important to limit the increase in risk and the rising cost of damage. Thus, the focus has shifted more towards land use and the associated potential damage. Risk-based spatial planning factors in all threat levels, identifies and visualizes current and possible future risks. In this way, the trend of risks can be managed by avoiding new risks and mitigating existing ones. The principle is to impose planning conditions in all areas in which a threat exists [16]. New land uses today challenge the capacity of communities to protect their present values and livelihoods using traditional and even re-conceptualized traditional land use tools to meet these engaging challenges in familiar ways. By far, these risk based land use planning tools represent a cultivated type of government aimed at reducing risks while maximizing environmental, economic and social opportunities. These tools permit communities to tackle issues as they arise and help them to adapt to new situations. In some countries where disasters often occur, mitigating risks during development has become crucial. New Zealand is today one of the leading countries in risk based land use planning providing a plethora of tools such as legal, monitoring and participation to effectively decrease risks associated with land development [16]. Right now, risk based land use planning is critical to create resilient communities. For example, [17] declare that communities suffer less in terms of property and lives during natural disasters when governments make the right choices in risk based land use planning. Likewise, [18] stress the importance of risk based land use planning focusing particularly on legal tools including legislations and policies to achieve this objective. The European Union even considers some risk based land use planning techniques to account for accidents during the land use planning exercise [19]. What's more, land use practices and human activities heavily impact on fragile ecosystems like wetlands, so careful evaluation and planning must be carried out prior to construction in these regions. For instance, Reference [20] used a GIS based framework to manage a RAMSAR watershed in Portugal. Similarly, Reference [21] developed three tools for land use planning in the Sampete Valley, Utah, United States to manage ground water contamination in the aquifer. These tools include ground-water classification maps, ground-water recharge-area maps and the septic tank density maps. In the same manner, some regions are naturally prone to natural disasters such as riverine locations or mountainous zones. In these places, careful evaluation and planning is needed to begin land use development and to mitigate risks over time. Reference [22] thus discuss the need to associate regulatory tools and more robust planning tools which include climate change considerations to minimize the effects of disastrous events like bushfires on life and property in Australia. Similarly, Reference [23] use a hazard and risk assessment in the eastern flank of

the Menoreh Mountains, Yogyakarta Province, Indonesia, to evaluate landslide risk for risk prevention and land use planning. In the same vein, Reference [24] consider risk and cost-effectiveness assessments to prioritize safety measures to deal with floods and landslides in Norway while [25] present the application of GIS tools to assess the risk of landslides and risk zones in the Balik Pulau area in Penang Island, Malaysia.

4.4. Risk based land use planning in Mauritius

Risk based land use planning is still a new concept in Mauritius though certain measures are implemented in the traditional land use process to decrease risks at vulnerable sites. For example, to regulate the development of large scale projects in the coastal zone, the EIA/PER mechanism has been set in place under the Environment Protection Act with district councils and municipal councils having the responsibility to issue building and land use permits [26]. Moreover, as part of the 'Making Cities Resilient' programme under the UNDRR, in 2019, members of local authorities and other relevant stakeholders were trained in using the Quick Risk Estimation (QRE) tool and Disaster Resilient Scorecard for Cities [27]. Nevertheless, all these measures are based on the likelihood of an event occurring with little consideration of the consequences associated with natural hazard events. This thus leads to decisions that place developments and communities at risk.

4.5. Proposed framework for Mauritius: Participatory/GIS-based approach for risk reduction

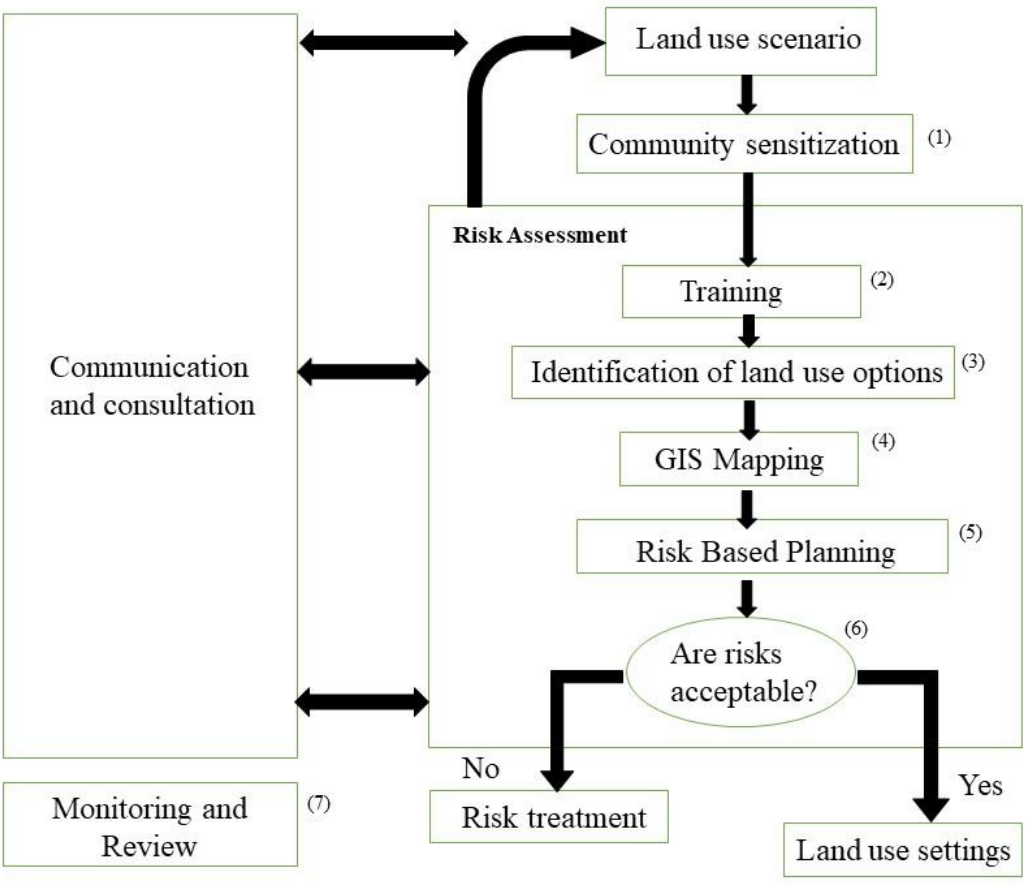

Figure 1: Proposed 7-steps risk based land use planning framework for Mauritius

A practical approach that could assist planners to incorporate risk into land use planning decisions in the Mauritian context is a community participation approach coupled to the technological visualizing tool, GIS. This 7-steps 'Participatory/GIS-based' innovative tool (Figure 1) provides local planners with a process that responds to challenges they face in adopting a risk-based approach with community participation as the main tool. It includes strategies to sensitize community members and engage communication with key stakeholders across local government and vulnerable communities. It assesses the current problems related to land use and takes into consideration people's understandings of cause and effects of these problems. GIS is a key tool in translating this valuable information into a visual reality and therefore helps stakeholders to make the right decisions.

The participatory/GIS based framework is a simple yet effective method to gather land use information and monitor projects. It is divided into the following steps: community sensitization, training, identification of land use options, risk based planning, GIS mapping, determining the level of risks and monitoring.

4.5.1. Community sensitization

In the first step of the approach, workshops for data gathering, meetings with community members, leaders, organizers and researchers are organized. In order to ensure active participation of all participants, they can also be grouped into focus groups based on age, gender etc.

4.5.2. Training

The second step is based on [28] training module on participatory planning and management as part of the FAO's development priority in Asia and the Pacific. Officials must be equipped with knowledge and tools to carry out the task as necessary. Consequently, a training workshop is mandatory to introduce the community workers, leaders and researchers to the basic concepts of participatory land use planning, the different stages and tools.

4.5.3. Identification of land use option

The aim of this phase is to identify land use problems, causes and effects. Here, focus groups can be organized based on various criteria in order to understand land use problems holistically. The existing situation to learn about land use problems, people's understanding of the causes and effects and how they cope with such situations is first assessed. This assessment can be done in different focus groups that targets specific members. Communication must be simple in the language of the community members and interpreters must be available if need be. Researchers must carefully document all discussions to evaluate afterwards. Following this assessment, alternative land use options are discussed with the participants. Solutions and coping strategies are suggested and two- way-communication is ensured between researchers and participants.

4.5.4. GIS mapping

In this step, participatory mapping is conducted. Information from all the above-mentioned steps is translated

into visual maps using GIS. The aim is to discuss locations where specific actions take place and reproduce an integrated alternative land use map that represents the shared vision of all participants. Each focus group can work with a topographic map of the region with pictograms that represent land use options. All the information from the different focus groups is put into a single map. Each of the option mentioned by the participant can be assumed to be a point which can eventually be converted into maps on ArcGIS.

4.5.5. Risk based planning

This step is based on [5] risk based planning approach. It is a full assessment of consequences of risks as well as the likelihood of natural hazard events. It enables natural hazard policies to be monitored to evaluate their effectiveness and to reduce risks. While in step 3 information was gathered from community members that live in the affected area, here, information is gathered from technical experts from emergency planners to scientists with expertise in the area. Consequences of natural hazard events like coastal erosion, flood extents and tsunami inundation zones in relation to known land uses within the hazard zone such as residential and commercial zones are calculated using a consequence matrix. Levels of risks as a function of consequences multiplied by likelihood is determined based on a risk scale from 1 to 25, 1 being extremely low and 25 as extremely high. Once the levels of risk have been determined, the matrix can be color-coded into thresholds of acceptable, tolerable or intolerable risks.

4.5.6. Determine level of risks

If the level of risk is deemed acceptable, management and development can be initiated in a particular region. If not, alternatives must be considered.

4.5.7. Monitoring and review

Follow-up on the approach is crucial to assess its effectiveness. Once the participatory/GIS-based approach for risk reduction has been used in one region, it must be monitored and reviewed as need be. Both topography and disasters are dynamic in nature and not static; as a consequence, frequent motoring and review of the above mentioned steps must be carried out to decrease risks associated with land use planning.

4.6. Justification of the Participatory/GIS-based approach for Mauritius

As stated by [10], there are several tools and frameworks for risk based land use planning; it is the responsibility of local authorities and stakeholders to come up with the most appropriate one context wise. Mauritius as a small island nation is currently undergoing rapid development with conversion of agricultural land close to rural areas into urban spots. Consequently, local communities represent the number one priority to consider for land use changes. Natives who have inhabited certain regions for generations generally have better knowledge about local disasters and solutions on how to mitigate these problems. By consulting local inhabitants, reluctance for developmental projects may be lowered and more effective localized solutions can be implemented in the face of dangers. Also, as [29] point out, the use of technological tools like GIS in risk based land use planning today has made it possible to integrate sets of images from different observational periods, sources and scales. By

using GIS to analyze the changes on land use and occupation, the evaluation in urban expansion, maintenance of morphological and socio-cultural features and the vulnerability of ecosystems can be monitored [29].

4. Conclusion

This study has summarized insights from over 90 studies that have been conducted on the tools and techniques used for risk based land use planning. A number of tools have been identified including legislative, organizational and administrative, economic, engineering and technical, modeling and monitoring and informative tools. At the same time, many planners use tailor made tools and techniques for the purpose of their own situations and justified for such applications. To date, planners are now incorporating risk management into land uses so as to decrease the impacts of disasters. From urban design to agricultural land, risk based planning has become an important step to achieve long term sustainability. Regarding the best framework in the Mauritian context, an innovative participatory/GIS-based approach for risk reduction has been proposed. It provides a framework for decision-makers that is simple for typical natural hazard management and to easily move the practice of planning for natural hazards forward in land use planning. It also takes into consideration both community members and technical experts' opinion throughout planning, with GIS as a powerful tool to visualize current land use options and to consider alternatives.

References

[1]. B.C. Glavovic. "The role of land-use planning in disaster risk reduction: An introduction to perspectives from Australasia". Internet: https://www.researchgate.net/publication/232581114_The_role_of_land-use_planning_in_disaster_risk_reduction_An_introduction_to_perspectives_from_Australasia , January, 2010. [Mar. 04, 2020]

[2]. K. Sudmeier-Rieux, U.F. Paleo, M. Garschagen, M. Estrella, F.G. Renaud and M. Jaboyedoff. "Opportunities, incentives and challenges to risk sensitive land use planning: Lessons from Nepal, Spain and Vietnam". International Journal of Disaster Risk Reduction, vol. 14, pp. 205-224, Dec. 2015.

[3]. F. Roy and Y. Ferland. "Land-use planning for disaster risk management". Land tenure journal, vol. 1, Jun. 2015.

[4]. P. Vangansbeke, L. Gorissen and K. Verheyen. "Bosland: Application of the Ecosystem Services Concept in a New Style of Forest Management". Ecosystem Services: Global Issues, Local Practices, pp. 397, Jan. 2013.

[5]. W.S. Saunders and M. Kilvington. "Innovative land use planning for natural hazard risk reduction: A consequence-driven approach from New Zealand". International Journal of Disaster Risk Reduction, vol. 18, pp. 244-255, Sep. 2016.

[6]. D. King, Y. Gurtner, A. Firdaus, S. Harwood and A. Cottrell. "Land use planning for disaster risk reduction and climate change adaptation." International Journal of Disaster Resilience in the Built Environment, Apr. 2016.

[7]. E. Tiezzi. Ecosystems and sustainable development VI (Vol. 6). Southampton, Boston, 2007, pp. 6-55.

[8]. B. Bajracharya, I. Childs and P. Hastings. "Climate change adaptation through land use planning and

disaster management: Local government perspectives from Queensland". In 17th Pacific Rim Real Estate Society Conference, 2011, pp. 16-19.

[9]. B. Jeyapragash, A. Muthuraj and T. Rajkumar. "Research Publications in Open Access with Special Reference to Directory of Open Access Journal an Analysis". International Refereed Journal, Journal of Current Trends in Library and Information Science, vol. 3, 1-2, pp. 4-9, Jan. 2016.

[10]. B. Amler, D. Betke, H. Eger, C. Ehrich, U. Hoesle, A. Kohler, C. Kösel, A.V. Lossau, W. Lutz, U. Müller and T. Schwedersky. "Land use planning methods, strategies and tools". Universum Verlagsanstalt, Eschborn, Germany, 1999.

[11]. ISDR. "Hyogo Framework for Action 2005 2015: Building the Resilience of Nations and Communities to Disasters: Extract from the final report of the World Conference on Disaster Reduction". A/CONF.206/6, International Strategy for Disaster Reduction, Geneva, 2007.

[12]. ISDR. "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters: Mid-Term Review 2010-2011", International Strategy for Disaster Reduction, Geneva, 2011.

[13]. S.T. Lovell. 2010. "Multifunctional urban agriculture for sustainable land use planning in the United States". Sustainability, vol. 2, 8, pp. 2499-2522, Aug. 2010.

[14]. L.T. Robert. "Land use planning, coastal inundation and coastal erosion in Tasmania". Doctoral thesis, University of Tasmania, Australia, 2010.

[15]. R. Camenzind and R. Loat. Risk-based spatial planning: Synthesis report on two case studies at communal land use planning level. National Platform for Natural Hazards/Federal Office for Spatial Development/Federal Office for the Environment, Bern, pp. 21, Dec. 2014.

[16]. W. Saunders, J.G. Beban and M. Kilvington. "Risk-based land use planning for natural hazard risk reduction". Lower Hutt: GNS Science, pp. 97, Sep. 2013.

[17]. R.J. Burby, R.E. Deyle, D.R. Godschalk and R.B. Olshansky. "Creating hazard resilient communities through land-use planning." Natural hazards review, vol. 1, 2, pp. 99-106, May 2000.

[18]. L.C. Struik, L.D. Pearce, F. Dercole, J. Shoubridge, S. van Zijll de Jong, J.D. Allan, N.L. Hastings and J.J. Clague. Risk-based land-use guide: safe use of land based on hazard risk assessment. Geological Survey of Canada, 2015.

[19]. M.D. Christou and M. Mattarelli. "Land-use planning in the vicinity of chemical sites: Risk-informed decision making at a local community level". Journal of Hazardous Materials, vol. 78, 1-3, pp. 191-222, Nov. 2000.

[20]. J. Alonso, J. Rey, P. Castro and C. Guerra. "GIS based land use planning and watershed monitoring as tools for sustainable development". In Ecosystems and Sustainable Development VI, Tiezzi, E., Marques, J., Brebbia, C. & Jorgensen, S., Editors, WIT Press, 2007 Sep:205-14.

[21]. J. Wallace, M. Lowe and C.E. Bishop. "Science-based land-use planning tools to help protect ground-water quality". Sanpete Valley, Sanpete County, Utah, 2017.

[22]. M. Buxton, R. Haynes, D. Mercer and A. Butt. "Vulnerability to bushfire risk at Melbourne's urban fringe: the failure of regulatory land use planning". Geographical research, vol. 49, 1, pp. 1-12, Feb. 2011.

[23]. D.S. Hadmoko, F. Lavigne, J. Sartohadi and P. Hadi. "Landslide hazard and risk assessment and their

application in risk management and landuse planning in eastern flank of Menoreh Mountains, Yogyakarta Province, Indonesia". Natural Hazards, vol. 54, 3, pp. 623-642, Sep. 2010.

[24]. E.B. Abrahamsen, J.T. Selvik and H. Berg. "Prioritising of safety measures in land use planning: on how to merge a risk-based approach with a cost-benefit analysis approach." International Journal of Business Continuity and Risk Management, vol. 6, 3, pp. 182-196, Aug. 2016.

[25]. B. Pradhan, S. Mansor, S. Pirasteh and M.F. Buchroithner. "Landslide hazard and risk analyses at a landslide prone catchment area using statistical based geospatial model." International Journal of Remote Sensing, vol. 32, 14, pp. 4075-4087, Jul. 2011.

[26]. Government of Mauritius. "Mauritius Environment Outlook Report". Internet https://wedocs.unep.org/handle/20.500.11822/8593 , January 2011 [May. 05, 2020]

[27]. UNDRR. "Workshop on urban risk reduction and making cities resilient: towards the development and implementation of local disaster risk reduction strategy". Internet https://www.preventionweb.net/files/66452_AGENDA%20-%20Mauritius%20local%20workshop.pdf , July 2019. [May. 05, 2020]

[28]. S.P. Jain and W. Polman. A handbook for trainers on participatory local development. Food and Agriculture Organization of the United Nations, FAO Regional Office for Asia and the Pacific Bangkok, Thailand, 2003, RAP publication, p. 07.

[29]. M. Monteiro and A.O. Tavares. "What is the influence of the planning framework on the land use change trajectories? Photointerpretation analysis in the 1958–2011 period for a medium/small sized city". Sustainability, vol. 7, 9, pp. 11727-11755, Sep. 2015.