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From Knowledge to Wisdom

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Let Nature Do the Work: Effective Strategies for the Restoration of Drastically Disturbed Sites

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Abstract: Natural systems have been "restoring" disturbed sites (landslides, volcanic eruptions, shoreline erosion, etc.) for millions of years. By understanding how these natural systems operate they can be applied to sites humans disturb (mines, industrial developments, etc.). Natural systems initiate recovery using pioneering species such as willows (*Salix* spp.), balsam poplar (*Populus balsamifera* L.) or alder (*Alnus* spp.). The seeds of these species are designed to travel long distances and use commonly occurring conditions to get established. Balsam poplar and willows have light fluffy seeds that at some times of the year look like snow. They land on puddles or other waterbodies and are blown to the wet mud at the edges of the puddle or on the shore of the waterbody where they germinate and grow. By creating these conditions (making puddles) on a mine site these species can be encouraged to establish on sites that are being reclaimed. The cost of these treatments is a fraction of traditional reclamation costs and because the resulting vegetation is appropriate to the area and the site where it establishes, natural processes can provide effective strategies for the reclamation of mining disturbances. Examples are drawn from the author's experience.

Key words: Natural processes, pioneering species, low cost, ecologically appropriate, successional processes, filters (constraints), human disturbances.

1. Introduction

Reclamation of drastically disturbed sites such as mines and industrial disturbances can often be a costly endeavour. Regrading angle-of-repose waste rock dumps can be very expensive if the waste dumps are high relative to the dump platforms. The concept of "wrap around" dumps can greatly reduce the cost of regrading [1] as the angle-of-repose slope is reduced. Similarly, the use of strategies that have been used in agriculture and forestry has been found to be expensive and of limited recovery value. The idea that a dense cover of seeded grasses and legumes would foster recovery came from agriculture as agricultural lands were often covered with agronomic species that were then plowed under to add organic matter to the soil. However at a mine site seeding with grasses and legumes was found to limit the recovery of sites. In many cases sites that were seeded with grasses and legumes at the time of the first Technical and Research Committee on Reclamation conference are still covered by grasses and legumes with no sign of real recovery [2].

Forestry approaches have not fared much better [3] as often late successional species were planted on sites that are ecologically at an early successional stage. Understanding the recovery processes allows effective treatments to be applied. Traditional reclamation treatments have failed to restore the ecological services that were found at many mine sites prior to mining. This has resulted in a loss in social licence. Building effective restoration also builds social licence.

Natural processes have been restoring drastically disturbed sites for millions of years. By understanding how these natural processes operate to restore disturbed sites these same natural systems can be applied to sites that have been disturbed by humans [4]. Natural successional processes starting with bare ground and colonized by pioneering species can build

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soils in areas where no soils (in the traditional sense) are present. In coastal areas, red alder (*Alnus rubra* Bong.) is a commonly occurring pioneering species that can build soil in areas with no soil [5]. At reasonable densities red alder can have a beneficial effect on the growth of conifers [6]. Alder fixes nitrogen and the leaf litter from red alder builds soil carbon levels. Similarly, balsam poplar (*Populus balsamifera* L.) can build soils in riparian areas where fresh gravel is the dominant substrate. Willows (*Salix* spp.), a common pioneer throughout North America have features that allow them to survive in harsh conditions such as on gravel bars in the middle of rivers [7]. In addition to building soil carbon reserves, willows can also provide important structural elements in the ecosystems where they grow. This is why they are successful as riparian species.

This paper provides information on creating the right conditions for pioneering species and on avoiding the filters that often occur at mine sites. Since these processes are based on natural systems, they are inexpensive and do not rely on non-natural materials. By following the natural recovery systems that have operated for millions of years, mine restoration strategies can be developed that are both inexpensive and effective.

2. Creating Appropriate Conditions

Hobbs and Suding [8] classified the constraints that restrict recovery as being either abiotic or biotic while Temperton, et al. [9] have defined the specific filers or constraints that operate. At mine sites, most of the filters are abiotic and include elements such as steep slopes, compaction, adverse textures, adverse nutrient status, adverse chemical properties (e.g. ARD (Acid Rock Drainage)), temperature extremes (dark substrates at many coal mines), adverse micro-climatic conditions and excessive erosion. Biotic filters include elements like herbivory—seeded grasses and legumes create pastures for deer and elk that then prevent the growth of shrub layers that limit the success of songbirds [10]. In addition, biotic filters such as competition can also play a role in preventing recovery.

It is essential that solving one issue does not introduce another. For instance, in the example given above where seeding agronomic grasses and legumes have traditionally been used to address erosion, the heavy cover of seeded species has allowed ungulates to prosper that then creates a problem with herbivory as well as competition for seedlings of woody species. Natural processes have evolved in a manner that avoids these issues so erosion in natural situations is controlled by the natural configuration of the ground and/or the vegetation that has established. How do natural processes control erosion? Naturally, water does not flow across the surface of the ground; it flows in the near-surface groundwater area. In a natural forest, the water that is delivered to the site by rain or snow is quickly injected into the near-surface groundwater zone. How does this happen? In high rainfall areas such as the Canadian West Coast, the dominant understory vegetation cover is salal (*Gaultheria shallon* Pursh) with tough leaves that have channels that move rainfall to the main stem and then down the main stem into the groundwater zone. Where salal is missing swordferns (*Polystichum munitum* (Kaulf.) C. Presl) take over the function of moving rainfall into the groundwater zone by their funnel like shape. Many of the plants that grow in coastal forests have evolved to move rainfall into the groundwater zone.

How does the ground surface function to control erosion? In a natural forest, the ground surface is rough and loose (topographic heterogeneity) and this has an influence on hydrology [11]. The falling of trees over thousands of years in a natural forest creates a rough and loose ground surface as the up-turned roots bring up large amounts of soil while the excavated hole that is left adds to the heterogeneity of the site. This is why water does not run across the ground in a natural forest, except in streams that are

fed by cool, groundwater flows that are important to fish and why cross-slope roads often have problems with seepage on the cut slopes.

These natural processes that effectively control erosion while not inhibiting the growth of forests can be used for the restoration of large industrial disturbances [12]. Making the ground rough and loose and scattering woody debris (100 m^3/ha) [13] on the surface can control erosion [14] by moving rainfall into the near-surface groundwater zone. In addition, making the surface of the ground rough and loose creates a diversity of microsites for seeds to lodge in and plants to grow and because there are a diversity of these microsites, a diversity of plants occur [12]. A former dam site that was restored using this treatment is dominated by red alder (35% cover in 5 years) with a high degree of diversity (84 species, including 5 different conifer species). Making the ground rough and loose is less expensive than traditional seeding. At a northern mine, treatment using the rough and loose technique costs $715/ha while traditional hydroseeding costs on the order of $3,500/ha. Rough and loose surface conditions can be constructed with an excavator using a digging (toothed) bucket. The bucket is filled with a large scoop of soil which is dumped half in and half out of the hole that was just opened. A second hole is then opened half a bucket width from the first and the material from this hole is deposited between the holes. The material between the holes should be loosened by jiggling the bucket as the second hole is opened. This process is continued until the comfortable swing of the excavator is reached. The excavator then backs up one bucket length and a new series of holes and mounds are created aligning the holes with the mounds in the previous row. Once the operator understands the objective, making a site rough and loose is a relatively simple operation that can be employed in a variety of locations from broad dump slopes to small exploration roads.

Natural processes create ecosystems that have a high degree of diversity with a high level of resilience for ecological changes in the future. This is due to the dominance of pioneering species in the context of developing recovery for the site. By creating a diverse context in which to grow, pioneering species foster the growth of a wide variety of species. Early successional plant communities are generally more diverse than their later successional counterparts [15]. This is important as it allows the community that is established to be resilient to changes that occur as the community matures. The role of pioneering species in creating diverse communities is essential to the success of these processes. The high level of diversity that occurs in natural plant communities allows these communities to create resilient ecosystems where they occur. Currently many of the western red cedar (*Thuja plicata* Donn ex D. Don) trees in coastal British Columbia are suffering due to extreme climatic conditions that are occurring. However, in a natural forest that is resilient, the loss of cedar trees does not mean that the forest disappears just that other trees that are more tolerant of the currently dry conditions will move in.

Working within the natural successional trajectories for the area in question creates conditions that avoid many of the problems that are often faced at mines. Invasive species are common at many mines due to the failure to address the filters that allow the natural successional processes to operate. Steep slopes can be addressed using wrap-around dumps [1] while regrading to a slope of 2:1 or 26° and making the surface rough and loose provides a context that allows the natural vegetation to establish. Since invasive species are rarely problems in natural ecosystems the creation of these natural ecosystems avoids the problems of invasive species. This is also true of seeding with agronomic species as it creates a condition that is outside of the natural successional trajectory so invites invasive species to establish. Thistles (*Cirsium* spp.) have been noted as part of the monitoring at a coastal mine since the late 1990s and

the biennial thistle, bull thistle (*Cirsium vulgare* (Savi) Tenore) has been increasing for several reasons. The relatively bare areas that are created when the alder that was planted at the mine in the late 1990s succumb to competition from the seeded grasses and legumes provide a context where this biennial species can establish and because the seeded grasses and legumes are outside of the natural successional context for the mine area (northern Vancouver Island). Although the alder that was planted was within the natural successional trajectory for the region, the seeded grasses and legumes are not within the natural successional trajectory and are influencing the recovery at the mine.

3. Maintaining Established Vegetation

Natural ecosystem processes are designed to maintain vegetation on a site forever so if the site is restored using natural processes by making it rough and loose and scattering woody debris then the maintenance of vegetation on the site will happen naturally. Early pioneering species have broad ecological amplitude so significant changes in the conditions of the ecosystem are unlikely to cause a significant change in the recovery of the site. In addition, early pioneering ecosystems are very diverse so that the demise of one species does not result in the collapse of the ecosystem. It is part of the ecosystem sorting itself out.

Using natural processes for the restoration of significantly disturbed sites like mines or industrial developments integrates the disturbed site into the natural recovery processes so that the natural processes take over maintaining the site. Ideas such as the need for rich soils or fertilizers come from the historic use of traditional treatments that are the foundations of agriculture. Similarly, the idea that the trees that were growing on the site are the ones to replant has fostered a problem with successional incompatibility where late successional species are established on an early successional site. Understanding how natural processes have restored disturbed sites for millions of years allows these processes to be used to restore and maintain sites that humans have disturbed.

4. Conclusions

Natural systems of recovery have been “restoring” disturbed sites for millions of years. By understanding how these systems operate they can be applied to human disturbances. Natural processes build soils on sites with no soil. Similarly, most natural pioneering species have seed distribution systems that allow the seeds of these species to colonize sites that are distant from the parent plants. In addition, these pioneering species often have attributes that promote the continued growth of the species in the areas where they occur so the willows growing on the riverbank create conditions that allow them to continue to grow in this area that is subject to frequent disturbances. The dense growth of willows on a riverbank slows the flow of passing water and allows sediments to drop out. As the willows can continue to grow with stems covered by sediment, the willows will continue to grow in these areas. These same processes can be used to control erosion and promote sediment collection at mines.

The use of natural processes and systems to restore drastically disturbed sites such as mines allows restoration costs to be significantly reduced. By addressing the filters that are preventing recovery (e.g. compaction, steep slopes, etc.) and creating conditions that promote the establishment of pioneering species these natural processes can be harnessed to restore sites that have been disturbed. In addition, these natural processes can be used to avoid common issues such as invasive species rarely grow in the pioneering ecosystems that initiate recovery on disturbed sites. So in addition to being much more effective than traditional reclamation treatments, the use of natural processes to restore mine sites is much less expensive than traditional treatments.

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Experimental Learning with Questionnaire Distribution for the Economic Evaluation of Industrial Pollution

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Abstract: During the 2016-2017 academic year, 3rd grade Gymnasium students from the Hellenic College of Thessaloniki received experiential training for the subject of Technology. For the needs of the course, students conducted research regarding the economic assessment of industrial pollution. A questionnaire was designed and distributed in order for students to collect information from individuals and households in the vicinity which the project of interest could potentially affect. The questionnaire aimed at identifying the maximum willingness to make a financial contribution with the use of assessing Hypothetical Scenario Methodology, which precisely assesses the economic value of an environmental good, since value is directly linked to the respondents' expressed preferences.

Key words: Experimental economics, environmental education, questionnaire, environmental good.

1. Introduction

Having mapped out the imperatives of society for further technological development, it becomes apparent that more and more young people are interested in studying in the field of Science and Technology. However, conventional teaching methods in the domain of science have been proved poor, a fact which justifies the gradual transition to a more student-centred educational system, as shown in the school curriculum and syllabus. The alternative teaching methods along with active experiential learning are expected to escalate students' interest and passion for science. Simultaneously, students' teamwork cultivates a number of social skills maximizing the benefits of technology through the use of it [1].

The subject of Technology in the Secondary School constitutes a prime example of how this trend can be realized in practice. Students in order to gain hands-on experience are practicing more and more on how to construct and discover knowledge. As a result, the school curriculum dictates for first graders to carry out individual assignments, for second graders group work and as for third graders, their training is developed through the "Research and Experiment" method. The experimental method actively involves students in the educational process and since it is also an experiential method, it is expected to maximize learning outcomes. Finally, the numerous and diverse thematic units which are suggested, make it possible to discover a number of different fields for research able to meet each student's personal preference [2].

The educational process implemented combines the following domains of inquiry: "The cultural, social, economic and political impacts of technology" (Unit 4), "The effects of technology on the environment" (Unit 5), "The role of society in the development and use of technology" (Unit 6), as stated in the curriculum. The combination of the above mentioned fields contributes to the development of critical thinking while simultaneously it is a great stimulus to cultivate the idea of what the role of an active citizen really is [3].

2. The Educational Process

At the beginning of the course a series of seminars and lectures were held by the educators aiming at informing the students on: (a) the research method in

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order to familiarize themselves with it as well as raise their interest by linking the research to real-life situations and (b) the technological areas from which students could draw information and choose a topic of interest. As a second step, students were asked to decide and divide themselves into five groups of five. This study analyses the research conducted by one of these five groups [4].

3. Methodology

The number of five students in each group makes sure that majority decisions are possible. As the project continued, the research was divided further into five sub-stages and at each of them the role of the team-leader/co-coordinator was taken by different students. After assessing relevant literature on industrial pollution, which was a topic of interest to the group, it has also been selected as a topic for research. "Economic assessment of the industrial pollution in the area of Elefsina" [4, 5]. This area raises particular interest as it is both an industrial and historical site. Consequently, industrial pollution causes a number of implications for both local residents and Greek citizens. The research question was defined as follows: "How much does the public good of clean environment cost to the respondent? [6]"

The stages of the research are described as follows:

(1) Bibliographic review of the Assessing Hypothetical Scenario Methodology;

(2) Questionnaire making process;

(3) Distribution of questionnaire-data collection;

(4) Data processing (in excel) ;

(5) Writing and presenting research findings.

The Hypothetical Scenario Method directly assesses the economic value of an environmental good because value is directly linked to the respondents' expressed preferences. It is also referred to as CVM (Contingent Valuation Method). The valuation for non-market goods comprises of empirical approaches and does not constitute a real science. Much of the criticism that the method receives is about how different the prices of such a survey are compared to the prices in a real market. The major weakness of the method is the hypothetical nature of the scenario created by the researcher [6].

The method is based on an individual's intentions to pay rather than on a real life situation. As a result, various types of bias may occur at different stages of the research. The "WTP (Willingness to Pay)" approach involves lack of precision and reliability, because in an effort to determine the value of the risk of error, interviewees often feel personally involved and they think their responds are somehow interconnected with or influence the specific evaluation [7].

The main advantage of the approach lies in the almost absolute control on the part of the researcher in the designing process. This approach can evaluate any good, whether there are market prices for it or not.

The assessment of the economic value of the environmental quality in the working environment or place of residence was based on two main criteria: (a) the estimated impact of the environmental quality on property value, which in turn reflects use values; (b) the will of the local residents to contribute financially to the relocation of the plant.

For the needs of the data collection a questionnaire was created with a view to gather information from individuals and households which lie within the area of interest. The survey ventured to discover residents' maximum willingness to make a financial contribution in order to completely avoid or reverse the effects and restore an environmental damage (WTP). Maximum WTA (Willingness to Accept) stands for the people's willingness to compensate in case of a new environmental damage. The preparation of the questionnaire was made after having taken into consideration the fundamental principles that guide scientific research along with the use of practical experience in the domain of environmental economics, taking into account the peculiarities of the particular case as well [7].

The questionnaire consists of sixteen questions, six of which refer to respondents' personal data. The number of questions was determined based on the collection of all necessary information within a reasonable time limit. The questions asked were posed in the simplest way possible, were multiple-choice questions with simple select or multi select answer and can be classified into the following categories:

(1) Closed-ended question measured on an ordinal and nominal scale;

(2) Open-ended question; and

(3) Semi-open question in combination with a nominal scale.

The three initial questions aimed at introducing the respondent to the research topic and the collection of qualitative data related to the degree of awareness of the problem as well as the potential benefits of creating job opportunities or any damage to the property value. The following questions addressed the core of the research, since they focused on the respondents' WTP or WTA to be compensated in order for them to relocate or tolerate the existence of the factory. The sum of money was to be determined with an open-ended question. In the last section, the main demographic data were collected.

The target group of the research consisted of inhabitants in the wider area of Elefsina. The sample size (150 people) meets the requirements of the research and conforms to the rules of the Statistical Science.

The survey was conducted in the industrial zone of Elefsina in March 2017, sampling a diverse sample of population. Additionally, questionnaires were distributed to factory workers of the area. The data collected were processed in Excel (students had the required knowledge from Descriptive Statistics courses).

4. Results

According to the findings of the survey, owners of property and tenants who live near the factory responded that the value of their estate was higher (about 64%). Approximately 8% reported that the value is not influenced by the presence of the plant, while about 28% answered that they did not know if the value of their house is affected. The majority (about 80%) who responded that their estate is undervalued due to the factory in their area, estimated the increase of their property value should be between 10%-50% (either as purchase or rental cost) while 20% of them claimed that the increase should be even greater. Interestingly, 7.5% of the respondents believe that their property value is eliminated (100%), because of the presence of the factory.

Based on the findings of all respondents who live near a factory, the average estimated decline in the value of housing is 37.3% and the median is 30%. The standard deviation was calculated to be 26.2%. Subsequently, the values of the house along with other variables (factory, distance, gender, income) were all examined in order for the researchers to identify whether there was a difference between the average obtained or not.

The presentation of the final project (with the units as defined by the syllabus) took place at the end of the school year. Each group presented their assignment first in the classroom, so as to take into account all comments made by the class assembly and work all necessary presentation skills. Then, all five groups presented their projects to the whole school at an arranged school event.

5. Conclusions

It is safe to conclude that students, through the role of the researcher, gained an insight and reaped multiple benefits from the whole process. Firstly, they were given the opportunity to examine the concept of Environmental Education and attempt to valuate, using Experimental Economics tools, the benefits and drawbacks of any factory for the neighboring area. They also came into contact with economics terminology and the Hypothetical scenario

methodology. The economic valuation of use and non-use values was based on two main criteria.

The students were asked to do research on an environmental problem away from their place of residence. Consequently, they had to enrich their knowledge with information (geographical, historical, cultural, financial) of the new area. The students involved had also to observe and admit the psychological pressure that the problem poses on them, since the Greek heritage is also undermined. Moreover, students were given the chance to relate their research to the living standards and development of a certain community and discover the benefits which technological research brings as well as the subsequent discovery of environmentally compatible production processes. During the research time, students mobilized their empathy, which positively contributes to initiatives and action in the area of interest. Such a thinking process inevitably leads to consideration of what an active citizen is meant to do, a concept that is a real challenge for modern education today.

The research method employed did not only add to students' knowledge but produced new knowledge per se. Students gradually understood why research promotes knowledge and creates new data and realized the citizen's responsibility towards examining the credibility of research findings.

What is more, students with the use of certain research tools made an effort to quantify qualitative data and even evaluate it in money. Inevitably, because of the difficulties they faced the students came to realize how hard it is to measure the invaluable value of public goods.

It is also worth-mentioning that cognitive benefits were gained from the IT, Statistics and Economics sector. The communication benefits were also invaluable since students came in contact with research participants and afterwards were asked to edit and disseminate outcomes and findings. Through team-work, leadership that changed in every stage, redistribution of roles and responsibilities, the students acquired strong social skills.

This whole process led students to familiarize themselves with the research process which made possible such a demanding task. Students became more and more autonomous within time and the fact that they knew since the beginning that the findings and outcomes of their project would be presented to a large audience, seemed to have had a positive effect on their engagement and commitment to the project.

Teamwork through students' interaction and collaboration appeared to maximize not only the final group outcome but also served individual objectives such as the personal achievement of a learning goal. The impact of experiential learning proved to be significant to the creation of a positive attitude for science learning too. Finally, even students' temporary relocation to the city of Athens, an urban environment quite different from their hometown (different place and population, environmental pollution, commuting with Tube/Tram they probably had never used before, etc.) adds to their learning and life experience.

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Assessing and Forecasting Saline Intrusion in the Vietnamese Mekong Delta Under the Impact of Upstream flow and Sea Level Rise

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Abstract: Saline intrusion is a hot issue and has always been of concern in the VMD (Vietnamese Mekong Delta), especially in the context of many changes of impact factors such as upstream flows and SLR (Sea Levels Rise). Vulnerability to changes in the upstream flows and SLR ismust-have reasons for updated and interpreted information. This information is used for exploiting of soil and water resources. MIKE 11 model was successfully applied to assess the saline intrusion. The study provided the picture of the saline intrusion in the dry season from January to May in the VMD in the existing situation (2015 and 2016) and the future (2030 and 2050) under the impact of flow at Kratie in various frequencies of 18%, 50% and 85% based on the time series of 2001-2016, and SLR according to RCP (Representative Concentration Pathway) 4.5 scenario of MONRE (Ministry of Natural Resources and Environment) of Vietnam issued in 2016. The results show that in the year 2015 the ASI (Saline Intrusion Area) in the VMD was relatively low due to moderate tidal level and high Kratie discharge (P = 18%). The scenario like the situation in 2016 and in the future ASI increased significantly compared to the 2015 baseline scenario which shows that the VMD is very vulnerable to saline intrusion. Based on multivariate regression analysis, the study also presented the formulas for the relationship between the ASI of 0.25 g/L, 2.5 g/L and 4.0 g/L thresholds and the impact factors such as the average discharge at Kratie and the maximum daily tidal level in East Coast during the dry season from January to May. With an adjusted R^2 at 0.913-0.974, these formulas are believed to be reliable for predicting ASIs based on the Kratie flow and the East Coast tidal level.

Key words: Saline intrusion, sea level rise, upstream flow, VMD.

1. Introduction

Saline intrusion is always a hot issue in the deltas where people exploit resources and live in concentration with high developing level. The saline intrusion in the estuaries and delta areas adjacent to the sea is a natural phenomenon and varieties are mainly depending on topographic conditions, tidal regimes and upstream flows [1, 2]. In the context of climate change, rising sea levels, along with the exploitation of land and water resources of people in the basin, the saline intrusion into the deltas and estuaries has become more and more complicated. The current status and prediction of saline intrusion as well as building a quantitative relationship between the saline intrusion and the impact factors such as upstream flow and SLR (Sea Levels Rise) always need to be updated and interpreted for sustainable management of soil and water resources in the delta.

The VMD (Vietnamese Mekong Delta) is located at the end of the Mekong River system with an area about 3.9 million hectares. This is a rich agricultural land, playing a very important role in Vietnam's national food security and export strategy, specifically

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in 2018, shrimp production reached 0.62 million tons, pangasius 1.41 million tons, fruit 4.30 million tons, rice yield 24.50 million tons, equivalent to 70%, 95%, 60% and 56% of the total national output respectively; and exports of key agricultural products accounted for 73.34% of the whole country [3]. However, the VMD is a flat lowland with dense river system and is influenced by the tides of the East Sea and the West Sea. The VMD is very vulnerable and always faced with saline intrusion disaster [4-6], especially during the dry season from January to May when the upstream flow is low. Recently, the saline intrusion had complicated with the fluctuations of upstream flows, climate change and SLR, it made more difficult for fresh water supply in the VMD. In the year 2016, the saline intrusion affected nine provinces in the VMD and caused great damage to almost economic sectors [7, 8].

The saline intrusion in the VMD under the impacts of upstream flows, climate change and SLR has been presented in previous studies [5, 6, 9-14]. They have indicated that the impacts of climate change, SLR and upstream flow changes increased the saline intrusion and negative impacts on water supply and agricultural products. However, the saline intrusion has been simulated in a part of VMD area and/or has not evaluated the factors affecting the saline intrusion. Khang, et al. [15] proposed the saline intrusion in the VMD under the impacts of SLR and upstream flow. However, the quantitative relationship between the saline intrusion and the impact factors such as SLR and upstream flow has not been determined. Tran, et al. [16] have only shown the relationship between the upstream flow change and the saline intrusion distance on some main rivers. On the other hand, the current upstream flow to the VMD has changed due to the regulation by dams in the upstream. The discharge during the dry season in the period from 2001 up to now at Kratie hydrological station is higher than in the past [17, 18]. Hence, the impact of upstream flows on the saline intrusion in the VMD has separately analyzed the flow time series at Kratie in different stages. Moreover, the current SLR and climate change scenario were changed, the RCP4.5 scenario of MONRE (Ministry of Natural Resources and Environment) of Vietnam issued in 2016 [19] was applied for the VMD.

Many studies [12-15, 20, 21] successfully applied one-dimensional HD (Hydrodynamic) and AD (Advection-Dispersion) modelling in the VMD such as MIKE 11 [22]. Duong, et al. [23] have used MIKE 21 two-dimensional model [24, 25], and Tran Anh, et al. [26] have integrated one-dimensional modelling and two-dimensional modelling such as MIKE 11 and MIKE 21 to simulate the flow and saline intrusion on the Hau River, one river branch in the VMD. With a large area, dense river network and many hydraulic works, while existing input data and computational capacity are not available, hence one-dimensional modelling such as MIKE 11 has been considered feasible to apply to the flow and saline intrusion simulation for the entire Mekong Delta [26].

This study focused on simulation of saline intrusion in the dry season from January to May in the VMD according to the existing and forecasting scenarios to 2030 and 2050. The MIKE 11 was applied to assess the impact of changes in upstream flows and SLR. The changes of upstream flow are determined in various frequencies using the discharge time series at Kratie during the period from 2001 to 2016. The SLR was based on the RCP 4.5 scenario, whereby the SLR is predicted to increase 12 cm by 2030 and 22 cm by 2050 in comparison with the existing period. In addition, from the simulation results, and the relationship between the ASIs (saline intrusion areas) in the VMD and the upstream flow, the sea water level will be explained through multivariate regression analysis.

2. Material and Methods

The methodological framework in this study is described in Fig. 1. Firstly, the fully collected and

processed input data and the MIKE 11 model were applied to simulate saline intrusion in the dry season from January to May according to the existing and future scenarios under the impact of changes of upstream flow at Kratie hydrological station and SLR to 2030 and 2050. Subsequently, the formula to quantify the factors affecting ASIs in the VMD was formulated through multivariate regression analysis.

The MIKE 11 model with NAM (Rainfall-Runoff), HD and ADmodules was used in this study. The MIKE 11 model was established in the range from Kratie hydrological station on the Mekong River and the Tonle Sap in Cambodia to the estuaries of the VMD and the lower Dong Nai River system in Vietnam (Fig. 2).

The hydraulic scheme consists of 988 tributaries with 7,189 cross-sections and 19,251 nodes, 147 major sluices to control saline intrusion in coastal zone of VMD and 120 water intakes.

In the hydraulic scheme, there are 8 upstream flow boundaries, 32 East Coast water level boundaries and 39 West Coast water level boundaries.

The specific model input data such as branches, and cross-sections and saline intrusion control structures are inherited from the data source of the SIWRP (Southern Institute for Water Resources Planning), the SIWRR (Southern Institute of Water Resources Research), and the BWE (Binh Minh Water & Environment Company Limited), and the terrain data were updated from the sources of the Department of

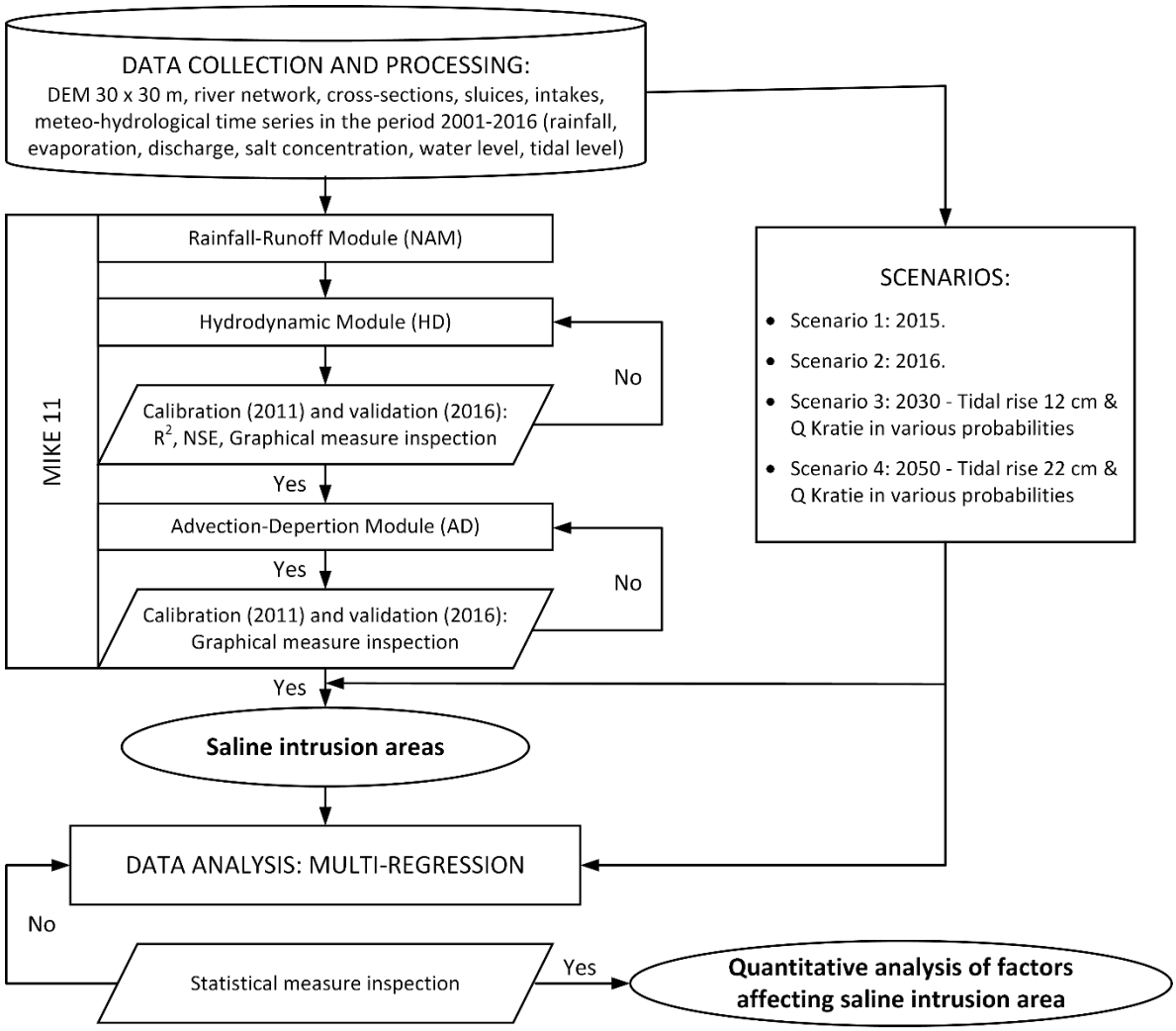


Fig. 1 Schematic framework of research methodology.

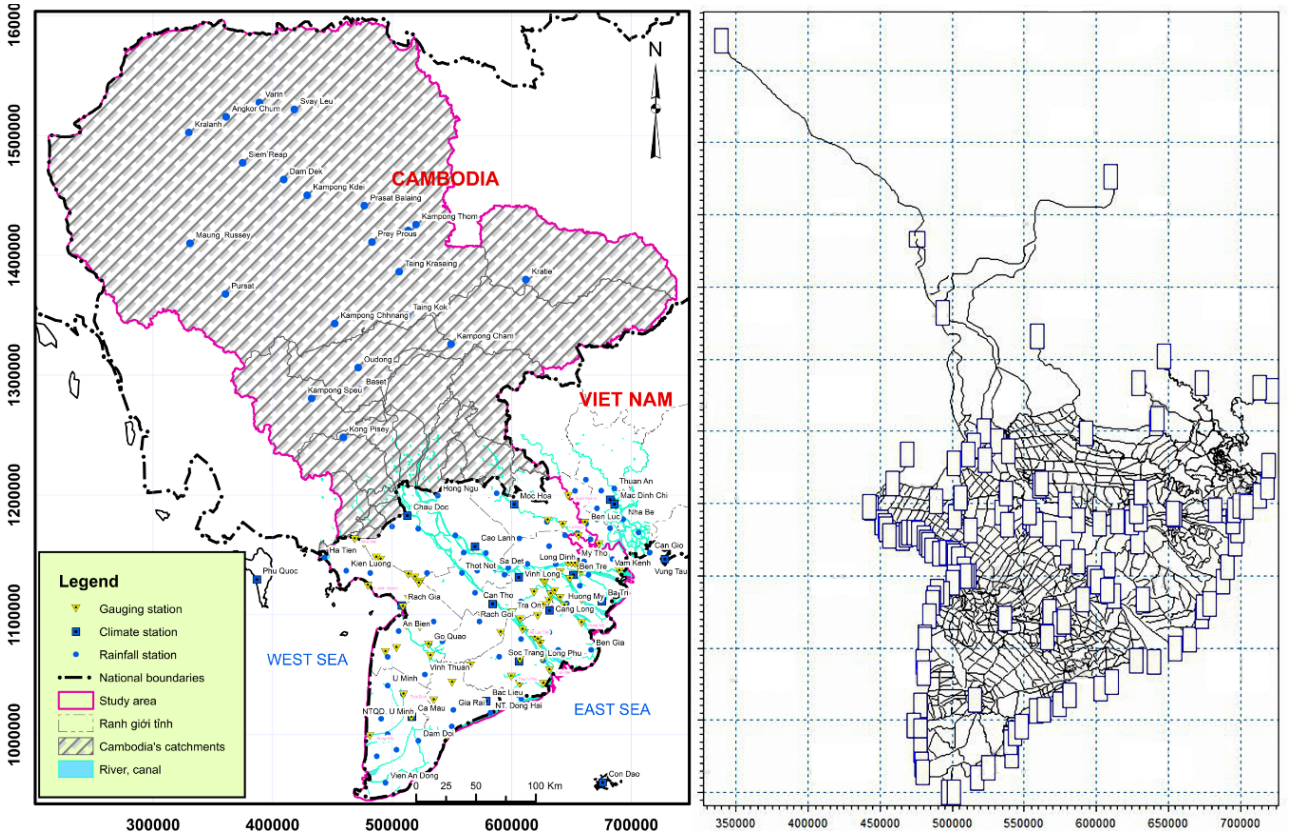


Fig. 2 Study area location and MIKE 11 scheme from Kratie and Tonle Sap (Cambodia) to river mouths (Vietnam).

Water Resources belonging to the provinces in the VMD. The DEM (Digital Elevation Model) 30 m × 30 m to delineate the sub-basins on the Cambodian side was downloaded from the U.S. Geological Survey [27]. The observed meteorological and hydrological data in the 2001-2016 period were collected from SIWRP, SIWRR, BWE and the Vietnam Meteorological and Hydrological Administration, including daily rainfall at 22 stations on Cambodia side. The set of NAM model parameters was referenced from the Dong Nai River basin which has similar conditions with the territory of Cambodia [28, 29].

To assess the saline intrusion during the dry season from January to May in the VMD, as well as for quantitative analysis between the ASI and impact factors such as upstream flows and sea level rise, four scenarios were built, including:

Scenario 1—Baseline scenario: The year 2015 was selected as the baseline scenario, in which the 2015 tide level is equivalent to the average tide level in the 2001-2016 period.

Scenario 2—Scenario of water scarcity in the existing period: Using the boundary conditions in the year 2016.

Scenario 3—Forecasting to 2030 under the impact: (1) Upstream flow changes at Kratie station wereconsidered in three cases of discharges such as: in the wet year 2015 with the frequency P = 18%, the average year P = 50%, and the dry year P = 85%; (2) SLR under RCP4.5 scenario with an average value of 12 cm higher than the baseline scenario is shown in Figs. 3 and 4.

Scenario 4—Forecasting to 2050 under the impact: (1) Upstream flow changes at Kratie station were considered in three cases of discharges such as: in the wet year 2015 with the frequency P = 18%, the average year P = 50%, and the dry year P = 85%; (2) SLR under RCP4.5 scenario with an average value of 22 cm higher than the baseline scenario is shown in Figs. 3 and 4.

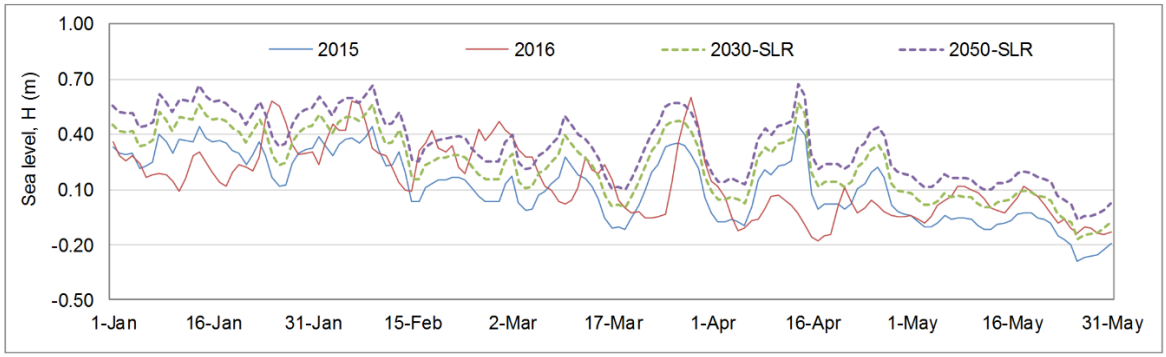
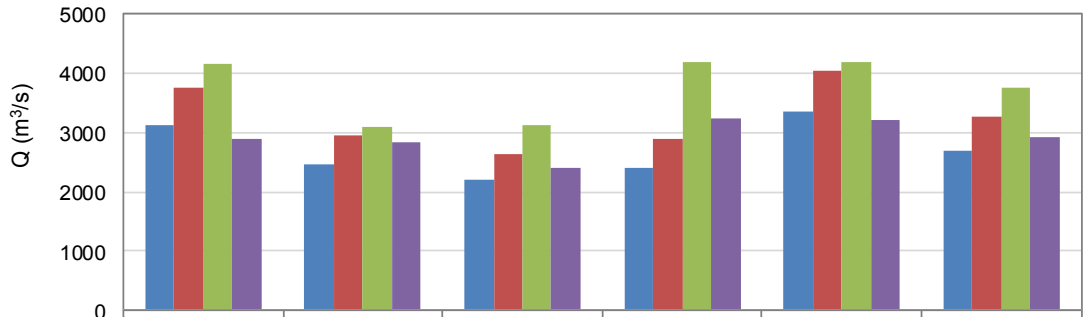


Fig. 3 An example of daily sea level at An Thuan station in various scenarios.



	Jan	Feb	Mar	Apr	May	Average
Q(P=85%)	3117	2459	2200	2400	3357	2706
Q(P=50%)	3752	2961	2648	2889	4041	3258
Q2015 (P=18%)	4170	3095	3126	4179	4181	3750
Q2016 (P=74%)	2907	2840	2403	3251	3212	2922

Fig. 4 Monthly observed discharge in the dry period from January to May at Kratie station.

3. Results and Discussion

3.1 Calibration and Validation of the MIKE 11 Model

The model was evaluated in two steps: (1) flow simulation; and (2) saline intrusion simulation. The model was calibrated during the dry season from January to May 2011, then validated during the period from January to May 2016.

HD model was calibrated through adjusting Manning coefficients, particularly Manning coefficient values ranging from 0.009 to 0.130 (mainly 0.03-0.04) for large rivers, and from 0.026 to 0.193 (mainly 0.045-0.055) on small tributaries. The results of calibration and validation the flow simulation are shown in Table 1 in terms of Pearson correlation coefficient, R^2 and NSE coefficient [30] at the hydrological stations in the VMD as shown in Table 1. The water level and discharge calibration and validation at Tan Chau station on the Tien River and Chau Doc station on the Hau River are shown in Figs. 5 and 6.

The Pearson correlation coefficient R^2 ranges 0.928-0.995, and the NSE coefficient ranges 0.780-0.980 during the calibration and validation of hourly water levels and discharges at hydrological stations in the VMD. It indicated that the MIKE 11 HD model has been applied successfully to simulate flows in dry season in the VMD.

For saline intrusion simulation, the model is calibrated by adjusting diffusion coefficient (D). The value of D ranges 200-1,000 m^2/s for large rivers and 20-300 m^2/s for small tributaries. The results of calibration and validation of saline intrusion are visually assessed through the graph of simulated salinity values and measured data at saline monitoring stations in the VMD during the dry season at the year 2011 and 2016 as indicated in Fig. 7; and comparison between the

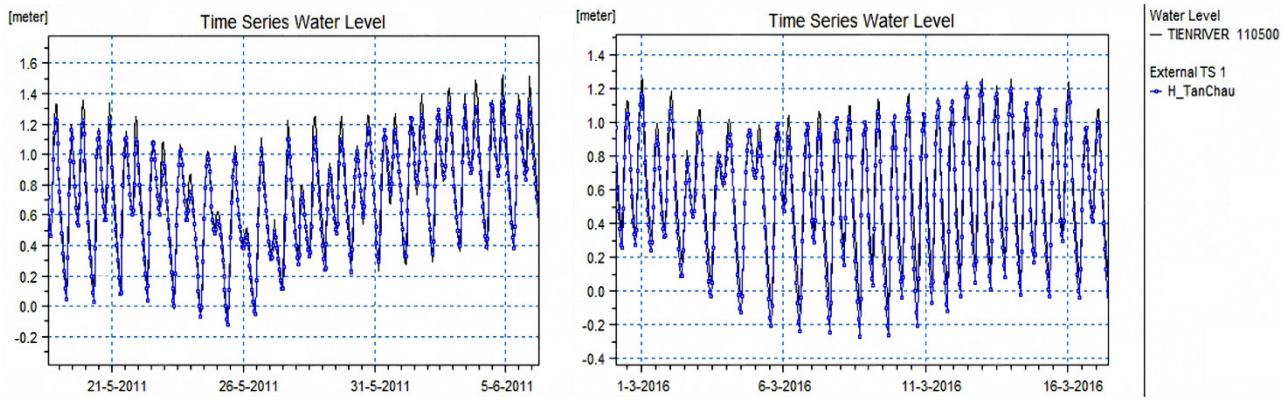


Fig. 5 Hourly simulated vs. observed water levels during the calibration (2011) and validation (2016) periods at Tan Chau station on the Tien River.

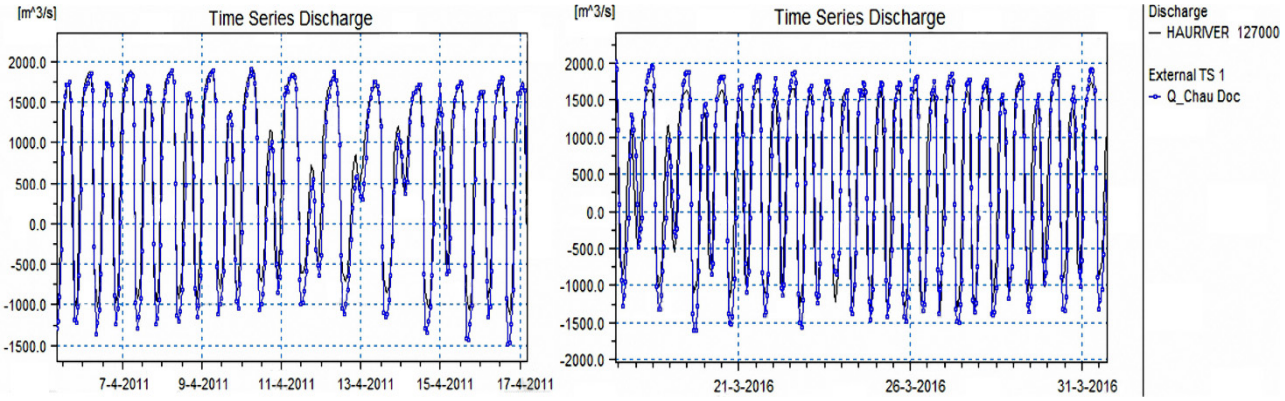


Fig. 6 Hourly simulated vs. observed discharges during the calibration (2011) and validation (2016) periods at Chau Doc station on the Hau River.

Table 1 MIKE 11 HD module performance in terms of Pearson correlation (R^2) and NSE (Nash-Sutcliffe Efficient) coefficient at hydrological stations in the VMD in the calibration (2011) and validation (2016) periods.

No.	Gauging station	Water level				Discharge			
		Calibration		Validation		Calibration		Validation	
		R^2	NSE	R^2	NSE	R^2	NSE	R^2	NSE
1	Tan Chau	0.928	0.780	0.980	0.943	0.967	0.915	0.976	0.944
2	Chau Doc	0.971	0.878	0.975	0.867	0.935	0.873	0.947	0.890
3	Long Xuyen	0.989	0.705	-	-	-	-	-	-
4	Vam Nao	0.989	0.943	0.984	0.916	0.933	0.858	0.957	0.883
5	Cao Lanh	-	-	0.984	0.941	-	-	-	-
6	Can Tho	0.967	0.935	0.983	0.965	0.966	0.925	0.971	0.941
7	Phung Hiep	0.974	0.963	0.960	0.920	-	-	-	-
8	Dai Ngai	0.987	0.969	0.987	0.968	-	-	-	-
9	My Thuan	0.993	0.972	0.993	0.962	0.952	0.898	0.964	0.927
10	Tra Vinh	-	-	0.995	0.968	-	-	-	-
11	Cho Lach	-	-	0.995	0.846	-	-	-	-
12	My Tho	0.990	0.980	0.954	0.905	-	-	-	-
13	Ben Luc	-	-	0.941	0.880	-	-	-	-
14	Tan An	0.958	0.901	0.969	0.856	-	-	-	-

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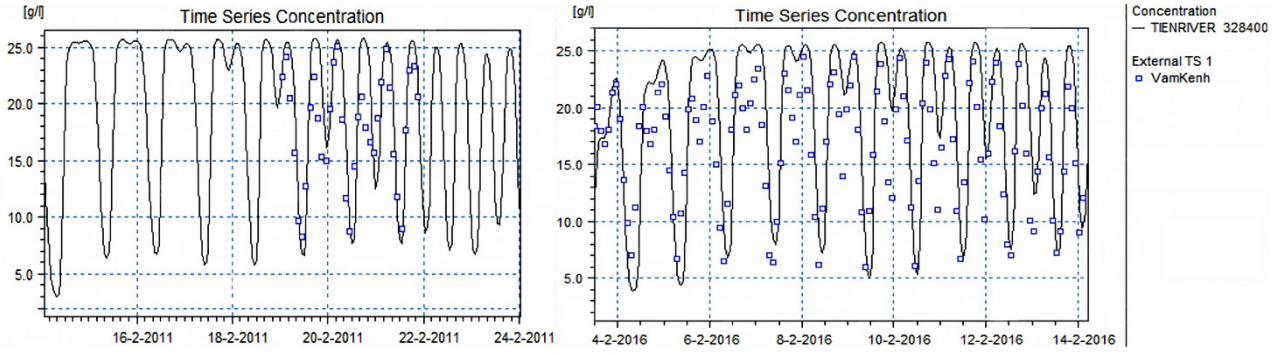

Fig. 7 Simulated vs. observed salinity concentration during the calibration (2011) and validation (2016) periods at Vam Kenh station on the Tien River.

Table 2 Comparison between simulated and observed distance from the river mouth to the saline boundaries of 1.0 g/L, 2.0 g/L and 4.0 g/L on some main rivers during the validation (2016) period.

River Branch	Saline boundary 1.0 g/L			Saline boundary 2.0 g/L			Saline boundary 4.0 g/L		
	Sim.[1] (km)	Obs.[2] (km)	Error[3] (%)	Sim.[1] (km)	Obs.[2] (km)	Error[3] (%)	Sim.[1] (km)	Obs.[2] (km)	Error[3] (%)
Vam Co Dong	137	135	1%	130	130	0%	114	115	-1%
Vam Co Tay	158	155	2%	147	145	1%	130	130	0%
Ham Luong	86	90	-4%	79	80	-1%	72	73	-1%
Co Chien	75	80	-6%	69	75	-8%	62	65	-5%
Hau	73	70	4%	70	67	4%	60	60	0%
Cai Lon	74	71	4%	69	70	-1%	63	68	-7%

[1] Simulated value; [2] Observed value; and [3] Error = 100 × (simulated value - observed value)/observed value.

simulated maximum saline boundary with the survey data of the SIWRP during the dry season 2016 as shown in Table 2.

Table 2 and Fig. 7 showed the agreement between the simulated salinity concentration values and the monitored data. Salinity values that differ from simulation and measured at locations mouth to the saline boundary of 1.0 g/L, 2.0 g/L and 4.0 g/L on the main stream showed: there are 15 cases ≤ 5% and only 3 cases from 6%-8% in total 18 observations.

3.2 Assessing Saline Intrusion according to Scenarios and Factors Affecting

The salinity thresholds of interest include: (1) salinity concentration of 0.25 g/L—the standard salinity threshold for domestic water [31]; (2) salinity concentration of 2.5 g/L—the standard salinity threshold for agriculture [32-34]; and (3) salinity concentration of 4.0 g/L—the salinity threshold for the crop yield affected by salinity [32-34]. The simulation results of saline intrusion during the dry season from January to May according to the various scenarios are shown in Table 3 and Fig. 8.

For the baseline scenario (2015), the ASI of 0.25 g/L, 2.5 g/L and 4.0 g/L covered 2.1676×10^{10} ha, 1.6767×10^{10} ha and 1.5549×10^{10} ha (Table 3), equivalent to 56%, 43% and 40% of the total VMD area, respectively. This is a year with relatively low saline intrusion because the tidal level is at an average in the existing period of 2001-2016 and the upstream flow to the VMD is large (Figs. 3 and 4), namely, from January to May the average discharge at Kratie is 3,750 m^3/s (corresponding to the frequency of 18% according to the standard distribution of flow data measured from 2001-2016).

For the year 2016 (Scenario 2) and the future to 2030 and 2050 under the impact of changes in upstream flow and SLR (Scenarios 3 and 4), the saline boundaries are much higher than the 2015 baseline scenario (Table 3 and Fig. 8). The main impacts of the

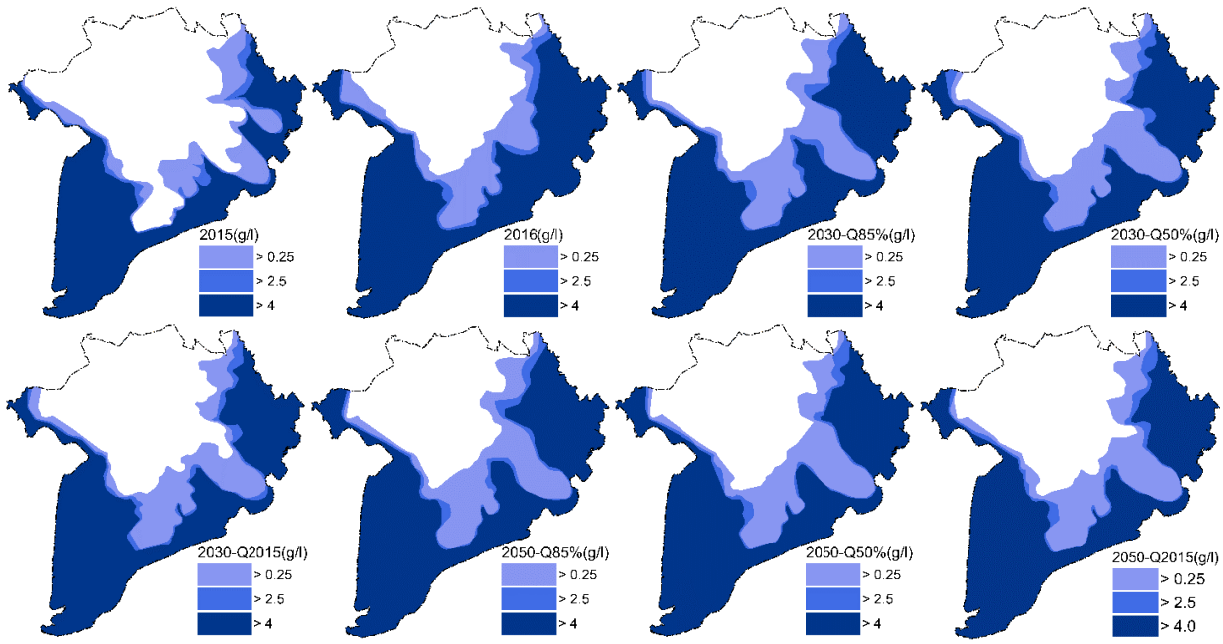

Fig. 8 Maps of the simulated ASI with the boundaries of 0.25 g/L, 2.5 g/L and 4.0 g/L in the VMD under the various scenarios.

Table 3 Simulated ASIs with boundaries of 0.25 g/L, 2.5 g/L and 4.0 g/L in the VMD under the various scenarios.

Scenario	Simulated ASI in various boundaries					
	0.25 g/L		2.5 g/L		4.0 g/L	
	Area (10^6 ha)	Increasing[1] (%)	Area (10^6 ha)	Increasing[1] (%)	Area (10^6 ha)	Increasing[1] (%)
2015 (Baseline)	21,676	-	16,767	-	15,549	-
2016	25,405	17%	18,618	11%	17,603	13%
2030 (Q2015)	23,939	10%	17,495	4%	16,479	6%
2030 (Q50%)	24,827	15%	18,084	8%	17,142	10%
2030 (Q85%)	26,101	20%	19,037	14%	17,973	16%
2050 (Q2015)	24,823	15%	17,972	7%	17,055	10%
2050 (Q50%)	25,255	17%	18,426	10%	17,392	12%
2050 (Q85%)	26,527	22%	19,555	17%	18,364	18%

[1] The values increase compared to the 2015 baseline scenario.

changes are: (1) tides and (2) upstream flows to the VMD. With tides, the VMD has been influenced by the tidal regime of the East Sea and the West Sea. The East Sea tide is a semi-tide with large amplitude (3.5-4.0 m), monthly the tide appears two spring tides and two neap tides, the maximum difference between the two tide periods is about 1.5-2.0 m. The West Sea tide is a irregular diurnal tide with small amplitude, usually the tide level is from 0.2 to 0.4 m, the tidal peak is from 0.6 to 0.8 m, and the largest amplitude is about 0.8-1.2 m. Based on the tidal characteristics, the saline intrusion in the VMD is mainly influenced by the East Sea tide. In addition, the West coast from Rach Gia to Ha Tien has anti-saline constructions, so the boundary of saline intrusion in this area has not changed much. With upstream flow, the flow into the VMD consists of two main sources, namely the Kratie flow on the Mekong River; and the contribution flow from Tonle Sap through the Hau River. The Tonle Sap with a mean storage volume of 49 billion m^3 that has affected the regulationof the flow for the VMD from Phnom Penh, thus the flow in dry months has been

increased. However, according to Toan [18], on average in March and April the contribution rate of flows to the VMD is about 26.5%, with drought year about 20.5%. Thus, the fluctuation of flow in Kratie plays a major role in the change of saline intrusion in the VMD.

From the point of view of the two main impact factors such as the flow at Kratie and the tidal level in the East Sea, the simulation is shown in Table 3 indicating the effects of their fluctuations on the ASIs in the VMD. With the effect of tidal fluctuations in the East Sea on the saline intrusion and high upstream flow (e.g. particularly the average dry season discharge at Kratie Q_{dry} = 3,750 m^3/s), the SLR of 1.5 cm, 3.1 cm and 2.2 cm then the ASI of 0.25 g/L, 2.5 g/L and 4.0 g/L will be increased 1%. With moderate upstream flow (Q_{dry} = 3,258 m^3/s) and the SLR increases 1.1 cm, 1.8 cm and 1.5 cm then the ASI of 0.25 g/L, 2.5 g/L and 4.0 g/L will be increased 1%. With low upstream flow (Q_{dry} = 2,706 m^3/s) and upto the year 2030 the SLR will be increased 0.6-0.7 cm then the ASI will be increased 1%, while in the 2030-2050 period the SLR will be increased 10 cm then the ASI of 0.25 g/L, 2.5 g/L and 4.0 g/L will be increased 2.5%.

With the effects of upstream flow fluctuations on saline intrusion and the low SLR (0-12 cm), the flow at Kratie will be decreased about 105-110 m^3/s then the ASI of 0.25 g/L, 2.5 g/L and 4.0 g/L will be increased 1%. When the SLR increases 12-22 cm and the dry season flow at Kratie is high (P< 50%) then the discharge will be decreased 200 m^3/s so that the ASI of 0.25 g/L, 2.5 g/L and 4.0 g/L will be increased 1%. In case the SLR is from 12-22 cm and the dry season flow at Kratie is low (P> 50%), the discharge will be decreased 100 m^3/s then the ASI of 0.25 g/L, 2.5 g/L and 4.0 g/L will be increased 1%.

3.3 The Relationship between ASIs and Kratie Flow, East Sea Tidal Water Levels

For ease of quantitative analysis of the relationship between the ASI in the VMD and the effects of the upstream flow and the tidal level, the method of multivariate regression was applied. The results of multivariate regression analysis have formulated the relationship between the ASI with the boundary of 0.25 g/L, $ASI_{0.25g/L}$ (10^6 ha); 2.5 g/L, $ASI_{2.5g/L}$ (10^6 ha); and 4.0 g/L, $ASI_{4.0g/L}$ (10^6 ha) and the impact factors such as the maximum daily tide level in the East Coast, $H_{day,max}$ (m) and the average discharge at Kratie, $Q_{dry,mean}$ (m^3/s), during the dry season from January to May as shown in Eqs. (1)-(3) and Fig. 9.

$$ASI_{\frac{0.25g}{L}} = 11{,}415H_{day,max} - 2.05Q_{dry,mean} + 24{,}680 \quad (1)$$

$$ASI_{2.5g/L} = 4{,}988H_{day,max} - 1.48Q_{dry,mean} + 20{,}088 \quad (2)$$

$$ASI_{4.0g/L} = 5{,}703H_{day,max} - 1.39Q_{dry,mean} + 18{,}322 \quad (3)$$

In terms of statistical criteria, specifically the adjusted R^2 equals 0.913 for $ASI_{0.25g/L}$ (as illustrated in Fig. 9a), 0.974 for $ASI_{2.5g/L}$ (Fig. 9b) and 0.965 for $ASI_{4.0g/L}$ (Fig. 9c), the multivariate regression model is

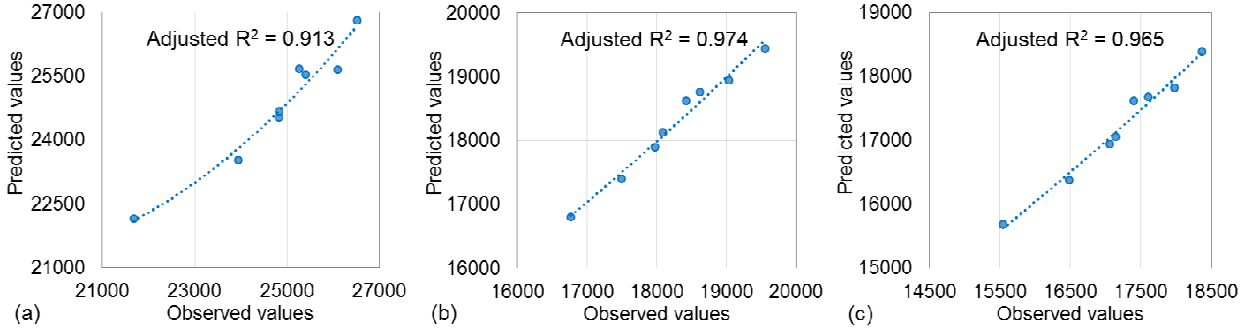

Fig. 9 Illustration of the regression analysis result of the relationship between ASI in the VMD and the changes of maximum daily tide level in the East Coast and average discharge at Kratie during the dry season: (a) ASI of 0.25 g/L, (b) ASI of 2.5 g/L, and (c) ASI of 4.0 g/L.

considered to be reliable. Furthermore, this very strong level of correlation reinforces the perception that without major human intervention altering the topography of the VMD (e.g. dykes, saline control sluices), the upstream flows at Kratie and the East Sea tidal level are the main factors governing saline intrusion in the VMD. Therefore, Eqs. (1)-(3) can be used to quickly predict the ASI with the boundary of 0.25 g/L, 2.5 g/L and 4/0 g/L under the impact of upstream flows and SLR during the dry season from January to May in the VMD.

4. Conclusions

This paper presents an assessing existing and future saline intrusion in the VMD under the impact of upstream flows and SLR by integrating the MIKE 11 model with the modules such as NAM, HD and AD, and also the method of multivariate regression analysis. The performance of the MIKE 11 model was evaluated using historical data in the dry season January to May at the hydrological and saline monitoring stations. Overall, the performance of the MIKE 11 model was excellent in estimating stream flow as demonstrated by the statistical measures including Pearson correlation coefficient R^2 having a range of 0.928-0.995 and NSE coefficient at 0.780-0.980 during the calibration and validation. It indicated that the MIKE 11 HD model has successfully simulated water level and discharge in dry season in the VMD. The MIKE 11 model was also excellent in estimating saline intrusion. The study has also provided a picture of the saline intrusion in the dry season from January to May in the VMD in the years 2015, 2016 and the future (2030 and 2050) under the impact of changes of upstream flow and SLR. The results showed that in 2015, the saline area in the VMD was relatively low. The scenario like the situation in 2016 and in the future ASI increased significantly compared to the 2015 baseline scenario. It can be concluded that the VMD is very vulnerable to saline intrusion in which two main governing factors have been clarified, namely the flow at Kratie hydrological station and the East Sea tidal level. From the simulation result of saline intrusion, the observed time series in the 2001-2016 period, and based on the method of multivariate regression analysis, the study also presented the formulas for the relationship between the ASI with the boundary of 0.25 g/L, $ASI_{0.25g/L}$ (10^6 ha), and 2.5 g/L, $ASI_{2.5g/L}$ (10^6 ha) and 4.0 g/L, $ASI_{4.0g/L}$ (10^6 ha) and the impact factors such as the maximum daily tidal level in the East Coast, $H_{day,max}$ (m) and the average discharge at Kratie, $Q_{dry,mean}$ (m^3/s) during the dry season from January to May. With the adjusted R^2 at 0.913-0.974, these formulas are believed to be reliable for predicting ASIs based on Kratie flow and East Coast tidal levels to support decision makers.

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Relationship between Concentration and Location of the Herbal Industry

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Abstract: Malaysia aspires to become developed and high income nation by year 2020. Under the Tenth Malaysia Plan, herbal industry was the first Entry Point Project for Agricultural National Key Economic Area in Economic Transformation Programme. To understand the current status of the herbal industry, FRIM (Forest Research Institute Malaysia) conducted the survey on 6,923 herbal chain players, consisted from upstream to downstream activities. A face-to-face interview was conducted using a structured questionnaire to gather the information. This paper highlighted the relationship between concentration of the herbal industry and urbanization's status of the areas. The finding shows that a statistically significant difference exists between category of herbal activities and status of the areas. The upstream activities are more concentrated in rural areas, while most of downstream activities in urban areas. It is in line with central place of theory on how settlements and places are located in relation to one another and their functions. Therefore, to further develop the herbal industry, the government should consider strategic location by category of industrial activities in policies planning, programmes implementation and providing infrastructural support needed by the industry.

Key words: Upstream, downstream, herbal industry, industrial location, central place theory.

1. Introduction

Malaysia is recognised as one of 12 top mega-biodiversity countries. Burkill [1] recorded around 1,300 plants used for traditional medicine in Malay Peninsula while Latif [2] reported around 2,000 plants with medicinal properties. The advantage aspired Malaysia to utilize its natural resources as sources of income and become developed nation by year 2020. Herbal industry was introduced as the first Entry Point Project for Agricultural National Key Economic Area in Economic Transformation Programme during the Tenth Malaysia Plan. The programme marks the government's seriousness in developing the Malaysian herbal industry as one of the major economic sectors [3].

The determination of the Malaysian government in developing the herbal industry is due to its economic potential. Global herbal medicine market is expected to reach 111 billion USD by end of 2023, projected to grow at a Compound Annual Growth Rate (CAGR) of around 7.2% during 2017-2023 [4]. Local market potential on herbal products is also huge. Recent survey on herbal products consumption estimated 72% of Malaysian adults consumed herbal products [5]. The finding is almost similar to the previous survey conducted by FRIM in 2013 which records 73% of herbal products consumption among Malaysian [6].

Study on business location especially on retail location has been explored long ago by researchers from various discipline. Clarke, et al. [7] in their paper explained the research tradition from the perspective of geographers and marketers in having a better understanding on the process of locational decision making. However, such studies on the Malaysian herbal industry are still lacking and it makes difficult to completely understand the distribution pattern of the industry.

2. Methodology

2.1 Data Collection

The data were originally acquired from study on

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value chain of herbal industry in Peninsular Malaysia. An extensive survey was conducted on the herbal industry players located throughout Peninsular Malaysia during 2014-2015. Updating of the first survey data (compiled in database known as HerbaXpress) was done from time to time starting 2016 until 2018 through different studies.

2.2 Data Analysis

Classification of urban, sub-urban and rural areas was done by referring to the delimitation provided by local authorities. Each of herbal player addressed was paired according to the respective group. Descriptive and independent samples Kruskal-Wallis Test were conducted to analyse the data.

3. Results and Discussion

The herbal industry players were formed with the group of PMS (Planting Material Suppliers), cultivators, product owners/manufactures, wholesalers and retailers. Most of herbal chain players operated in urban areas followed by sub-urban and finally rural. An average of 142 players distributed in each of 23 urban areas were identified in this study. A statistically significant difference ($H = 20.891$, $p < 0.01$) exists between overall number of herbal chain players by status of the area. The distributions were most likely influenced by group of downstream players as the group formed the majority (88%) of herbal chain players (Table 1).

Upstream players in herbal industry included group of PMS and cultivators. Three hundred and twenty-nine (329, 48%) of upstream players operated their business in rural areas while 248 (37%) operated in sub-urban areas. Only 101 (15%) of the upstream players operated in the urban areas. A statistically significant difference ($H = 7.279$, $p < 0.026$) exists between number of upstream players by status of the areas (Table 2).

Selection of suitable and strategic business location is crucial in production of products. Most of producers preferred sub-urban or urban areas to locate their business. Only 128 (23%) of producers decided to operate their business in rural areas. A statistically significant difference ($H = 8.979$, $p < 0.011$) exists between number of producers by status of the areas (Table 3).

Downstream players consist group of wholesalers and retailers. It is common for downstream players with outlets to set up their business in middle of

Table 1 Herbal chain players by status of the areas.

	N	Mean	Std. deviation	Std. error	95% Confidence interval for mean		Minimum	Maximum
					Lower bound	Upper bound		
Urban	23	142.22	179.772	37.485	64.48	219.96	3	657
Sub-urban	32	79.19	67.406	11.916	54.89	103.49	14	256
Rural	47	32.66	19.057	2.780	27.06	38.26	1	87
Total	102	71.96	102.269	10.126	51.87	92.05	1	657

$H = 20.891$**, p-value = 0.000.

** Independent-samples Kruskal-Wallis Test is significant at the 0.01 level (2-tailed).

Table 2 Upstream players by status of the areas.

	N	Sum	Mean	Std. deviation	Std. error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
Urban	23	101	4.3913	7.17786	1.49669	1.2874	7.4952	0.00	22.00
Sub-urban	32	248	7.7500	9.53432	1.68545	4.3125	11.1875	0.00	48.00
Rural	47	329	7.0000	9.76017	1.42367	4.1343	9.8657	0.00	60.00
Total	102	678	6.6471	9.17125	0.90809	4.8457	8.4485	0.00	60.00

$H = 7.279$*, p-value = 0.026.

* Independent-samples Kruskal-Wallis Test is significant at the 0.05 level (2-tailed).

Table 3 Number of producers by status of the areas.

	N	Sum	Mean	Std. deviation	Std. error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
Urban	23	206	8.9565	14.66126	3.05708	2.6165	15.2965	0.00	66.00
Sub-urban	32	214	6.6875	6.18759	1.09382	4.4566	8.9184	0.00	23.00
Rural	47	128	2.7234	2.98330	0.43516	1.8475	3.5993	0.00	15.00
Total	102	548	5.3725	8.32855	0.82465	3.7367	7.0084	0.00	66.00

$H = 8.979$*, p-value = 0.011.

* Independent-samples Kruskal-Wallis Test is significant at the 0.05 level (2-tailed).

Table 4 Number of downstream players by status of the areas.

	N	Sum	Mean	Std. deviation	Std. error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
Urban	23	2,964	128.8696	162.71121	33.92763	58.5080	199.2312	3.00	626.00
Sub-urban	32	2,072	64.7500	60.51180	10.69708	42.9332	86.5668	2.00	232.00
Rural	47	1,078	22.9362	13.30806	1.94118	19.0288	26.8436	1.00	67.00
Total	102	6,114	59.9412	93.26231	9.23434	41.6227	78.2596	1.00	626.00

$H = 25.718$**, p-value = 0.000.

** Independent-samples Kruskal-Wallis Test is significant at the 0.01 level (2-tailed).

location with high population. Hence, it is not surprising when 5,036 or 82% of downstream players operated their business either in urban or sub-urban areas. A statistically significant difference ($H = 25.718$, $p < 0.00$) exists between number of downstream players by status of the areas (Table 4).

4. Conclusion

The finding shows that a statistically significant difference exists between category of herbal activities and status of the areas. The upstream activities (supplying of planting materials and cultivations) are more concentrated in rural areas, while most of downstream activities (wholesaling and retailing) in urban areas. Deciding location in operating a business is important to the business owners. Theoretically, business locations have a direct impact on the operating costs and revenues. The findings are also in line with the Christaller's Central Place Theory (1933) on how settlements and places are located in relation to one another and their functions. The theory discussed concepts of central place, central goods and services, the range of a goods and finally the complementary region [8].

Even though the herbal industry has been developed for a long time, recent study from FRIM concluded the industry is still in infancy stage [9]. Farizah et al. [3] also highlighted several issues and challenges that curb the production of locally high-claim herbal products. These situations proved the needs of continued government assistances to further strengthen the industry. However, proper strategies need to be outlined to ensure the benefits from government programmes reach the targeted groups. Therefore, to further develop the herbal industry, the government should consider strategic location by category of industrial activities as one of the important criteria in policies planning, programmes implementation and providing infrastructural support needed by the industry.

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The Cattle Grooming Behavior and Some Problems with Technological Grooming Instruments for Cow Welfare

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Abstract: Thanks to grooming in cattle, dirt, dust and parasites that are removed, skin blood circulation is increased and muscles are massaged. However, grooming should be done with appropriate tools and equipment. Otherwise, it can be more damaging than benefit. There would be a risk that can hurt the animal's life if not paid attention, and may result in injury or even tail rupture. Animals exposed to such situations normally want to escape from grooming and show resistance even though they enjoy it very much. Inaccurate applications during the acclimatization period, the use of small and low-placed brushes that are not suitable for the size and structure of the cattle, malfunctions during the operation of the grooming brush and in the event of incorrect operation, the wounds occurring in different parts of the body can prevent the expected benefit from the use of the grooming brush. But many works carry on this subject to provide more efficient grooming instruments for cow comfort. And grooming is considered a potential indicator of positive welfare. The combination and integration of welfare instruments will ensure optimum wellbeing for dairy animals to maximize profitability. Use of welfare instruments combined with new technologies for information handling and integration to instruments give more effective results.

Key words: Cattle, grooming, behavior, technology.

1. Introduction

Cattle are herd animals and they feel safe as long as they maintain contact with each other. Grouping is seen during affection, patronage or comfort behaviors. When they perceive danger, animals get closer to each other. As social animals, they usually graze and rest in pairs. Social activities such as coexistence and mutual grooming strengthen group communication. In addition to social effect of grooming, healthy animal appearance can be understood from their clean thin, shiny and elastic skin. Because of these grooming which is natural, indispensable behavior of animals in terms of skin health's protection is very important in daily life. Grooming plays an important role in maintaining the efficiency of the animals at the expected level and in the healthy functioning of their thermoregulatory abilities and in maintaining their health. These creatures do groom by rubbing each other or licking each other or themselves with their tongues. Hands and fingertips of humans act as the most sensitive organs in perception, whereas in cattle, mouth, nose and lips serve this function. Grooming is an important behavior in terms of social hierarchy and performance of cows. Grooming behavior is very important for cattle's individual and herd district. If cattle cannot find grooming possibilities they showed abnormal behavior [1].

Self-grooming will often make use of environmental items in extensive production systems, to scratch on, such as boughs, brushes, trees, fences and posts, particularly for areas of the body inaccessible to the mouth, tongue and feet [2]. This behavior involves licking by tongue, scratching with their hind feet, scratching with their horns, and swatting with the tail in an effort to clean all areas of their bodies that they can reach [2]. To reach inaccessible parts, such as the head, neck, back, and hind quarters, cattle will often scratch themselves on inanimate objects. Georg and Totschek [3] reported

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that the frustration or stress occur due to boredom in intensive housing systems.

Grooming each other is a common behavior which is generally done according to the hierarchy within the flock. Grooming is a process in which many animals apply to each other to clean their bodies, skins and furs. Grooming starts with the head, continues with the back and sides and ends with the bottom of the tail. Grooming also means cleaning, stimulating capillaries, skin care and parasite control. The purpose of grooming is to remove vestigial hair and dead-cells of skin. All parts of the body can be reached by the tongue with a little pressure, licking behavior and grooming is done. They scratch their heads, ears and upper neck areas by using their hind legs and their back of the body by using objects such as trees or fences. Although the animals groom themselves on their own, there is also mutual grooming from time to time. This grooming form contributes to mutual communication and is usually initiated by cattle that are lower in the hierarchical order. The cattle stand side by side with one's nose on the other's tail and grooming areas that are not accessible to each other.

Cows are reported to be grooming themselves for at least 3 times a day and 1-1.5 minutes each time when a barn brush is installed. And the interesting point is that when the grooming brush was first put in the compartment, half of the cows in the herd came and tried it, although it was a new practice [2]. The research also shows the highest groomed body area with 11% of grooming cows' necks, 3% of thighs and 86% of head. In addition, cattle use the brushes to soothe by scratching their neck and the ears' back, which are sensitive to touch by using the brush [4]. Mandel, et al. [5] reported that the frequency of brush use decreases in case of stressful situations. It can be accepted that increased brush use may be indicator of positive emotional status of cows. Keeling, et al. [6] reported that each additional time the cow used the brush is associated with 0.75 kg higher milk yield per day ($p < 0.01$) and with 0.32 kg more dry matter consumed per day ($p < 0.001$). But brush usage decreased when cow was subjected to medical procedures [5]. Location of the brushes is also important to effective brush usage. Also barn temperature and humidity levels are effective to brush usage. Breed, lactation number, stage of lactation, dominance or affiliative rank of the cows are effective to brush usage rate.

Animals lick by their tongue and use saliva as secretion during grooming. Saliva is a special fluid produced by the salivary glands under the tongue in the mouth of the animal [6]. Salivary secretion contains many substances that provide digestion in the rumen and reduce the acidity in the rumen [7-11]. If digestive disorders occur the animal ruminates less and thereby reduce salivation. Microorganisms found in rumen which are beneficial for the digestion of the animal are damaged. There are two main factors that prevent relaxation and, consequently, salivation [11]. One is the ratio of roughage and the other is concentrate in total daily feed. The ratio of roughage in the total daily feed should be around 50%. However, the rate of roughage in very high yielding animals can be allowed to decrease up to 40%. Roughage rate should never be less than 40% in dairy cattle. Rough ration is reduced in underfed cattle in terms of roughage. The other is the chopping length of roughage. Very fine chopped straw, corn silage, such as roughage, as well as the structural fiber-poor fresh green tea grass and beet, tomato and apple pulp ruminant preventive effect. Therefore, such roughage must be mixed with hay or coarsely chopped hay. Feeding the feeds by wetting or slurring also reduces the salivation. The esophagus is a little shorter than 1 m and provides the passage of the feed mixed with saliva in the mouth to the rumen. Apart from these, it has no digestive activity.

A cow that consumes an average of 18.2 kg dry matter and produces 10 to 32 L saliva per kg of dry matter. Saliva quantity varies according to feed consumption and feed content [11]. Cattle have a large number of glands located around the mouth. Of these,

saliva is secreted with little difference between their compositions. Salivation is important in feeding cows. A cow with a good nutritional program releases about 180 L of saliva per day. The maximum salivation occurs during ruminating. An animal rises secretes 160 mL of saliva per minute. The saliva pH is 8.2. Rumen pH is between 5.8-6.2 [12].

Saliva with a mean pH of 8.2 and high sodium bicarbonate has a buffering effect in rumen. This means that saliva helps counteract the effects of acid-producing feedstuffs such as cereals, molasses, potatoes and fodder beets on rumen acidity level. In addition, saliva suppresses the foam in the rumen. It reduces the risk of swelling of saliva because it has foam suppression effect in rumen.

Saliva is a fluid that causes digestion to begin. Saliva, which breaks down starch to maltose and dextrin, facilitates digestion at other stages. Again, saliva destroys many possible bacteria in the mouth. However, the effect of these antibacterial compounds is insufficient unless regular cleaning of the mouth is provided. In addition, saliva breaks down tartars that remain in the mouth, sticks to the teeth and continues to decompose any feed residues that remain in the mouth. Some animals, such as snakes, also produce poison in their saliva-like organs to protect themselves from enemies.

2. Grooming Effect

Regular grooming improves cattle appearance, increases blood circulation, and stimulates skin, which make the cattle coat shiny. Fraser and Broom [12] reported the dopaminergic functions to all grooming. Researcher reported that the hormone prolactin is associated with grooming and has dopaminergic activity so grooming causes opiate induction and self-narcotization using prolactin way. Keeling, et al. [6] reported that time budget for cows was 42% lying, 27% walking or standing, 16% feeding, 10% queuing to be milked and 1% of their time drinking, using the brush or being milked. Cattle with access to mechanical brushes are cleaner and spend about fivefold more time grooming compared with when brushes are not available. Perhaps very little time schedules for grooming. Grooming is also a good opportunity for checking animal body for injuries, skin irritations or other health problems. Continuous cattle grooming will build trust and confidence between cattle and handler. Farmers develop a positive relationship with cattle during grooming. Grooming allows cows to bond with their herd mates and reduces the impact of the boss cow/submissive cow hierarchy within the herd. Cows also use grooming as a way to cope with stressful situations. But grooming effect is relatively important. The decrease in brush use might therefore occur before a decrease in milk production or an increase in sub-clinical signs [6]. When provided, 85 to 100 percent of cows in a herd used brush daily. And brushes improve cows' scratching time by six times. Milk production is also improved. Some researchers reported that the milk production is improved as a result of increased cow activity to use brushes and active cows utilize ketones more effectively on body reserve. Brush usage can also improve animal cleanliness. This could improve animal udder health and decrease mastitis risk.

After grooming, the skin on the salt, sweat, organic substances, such as eggs which is left by the flies and the external parasites are cleaned. Grooming is the behavioral characteristics of cows that promote health, calmness, well-being and overall performance. Grooming has a positive effect on animals, the formation of herd instinct, calm down of animals, prevention of skin diseases, cleaning of the skin; the blood flow in the skin is stimulated, prevents stress, increases animal welfare, the skin gets a healthier appearance, the stimulation of the nerves in the skin is easy to apply [14]. The overall objective of grooming cattle is to give them the best overall conformation. It is also known to increase milk yield by 10%-14%. The differences in the values of per day milk yield as

influenced by different treatments of bathing and grooming combinations in cross-bred cows during summer season are significant reported by Pandey and Neeraj [14]. Researcher reported that the cows groomed thrice and given bath twice a day give more milk 7,480 kg during the summer season and 5,513 kg for rainy season. Verma, et al. [15] reported that two times bathing and grooming in cross-bred cows under hot conditions may be used as effective routine managemental practices to obtain higher milk yield and its compositional quality as well as reduce heat stress during summer season. Researcher also reported that bathing and grooming were effective for increasing the fat percent in milk of crossbred cows. The cattle grooming improves feed intake up to a 3.5% rise in milk production. Schukken and Young [16] reported that the mechanical rotating brushes resulted in a significant increase in milk production of cows and a significant decrease in clinical mastitis.

Some country grooming brushes are mandatory for intensive dairy farms to provide comfortable environment. There are many types of grooming equipment on the market. Some of these tools are made of pliable plastic, some of them metallic while other wooden. Basic grooming tools are a comb, brush, scraper and grooming cloth. Cattle show big variation aspect of response grooming equipment. Some of them have greater sensitivity than others to grooming. Also, disinfection and care of grooming tools is very important and the use of tools from outside the farm increases the risk of disease. Also, necessary safety precautions should be taken when working with animals, because many activities contain risk such as leaning over to hooves, stooping to check legs, moving hay bales, repetitive motions in brushing and grooming, reaching above the head for grooming, tacking, etc. The grooming environment must be organized for safety.

3. Manual Grooming

In natural environments, cattle use trees and other abrasive surfaces to scratch and groom themselves. Modern indoor dairy cattle housing systems often lack appropriate grooming substrates, restricting the animals' ability to groom. The first time to work with a grooming cow waiting for the animal to approach the gently touching of the body of the neck is to groom. In the lapping process, grooming the neck and half of the body is more than sufficient. Touching the feet to grooming can cause the animal during the adaptation phase. Grooming the animal 2-3 times is enough to get rid of this type of negative response. The pressure that can be applied in the use of brushes and bowls depends on the animal's body area, skin thickness and brush characteristics. Before starting grooming, brush all over the cattle with a hard brush. However, hard brush should not be used in the compression and bony areas of the shallow. Dust and hairs are removed from the bowl with a soft brush. Grooming is completed by wiping with the last genre or towel.

If a cow cannot find cows to groom, they will approach the walls, pipes, timber or similar materials in the shelter and try to groom themselves with them. The skin is equipped with various receptors. There are receptors to detect movement in the skin, detrimental effects, hot or cold and pathological conditions. Lip, tongue, nipple and vulva are the most sensitive areas in cattle.

All cattle age groups, whether pastures or cows in the barn, want to relax and scratch themselves and use the many materials around them for this purpose. Friction on fence posts, sharp metal corners, scratching with rusty nails in buildings can cause negative effects such as opening, irritation, hair loss, scars and irritations on animals' skins. There are many materials developed against these negative effects. Itching pads, grooming brushes are the best examples. Animals should be groomed from time to time with the help of materials such as spoon, brush, sponge, comb and cloth.

For this reason, in recent years, many companies have developed brushes for grooming systems to

relieve animals and make them available to farms. These brushes are mounted in a stable place with a suitable height and inclination in the barn, and the cow comes to the side of the brush and gently starts to rotate when he starts rubbing his back with his head. Dairy cattle breeders state that cows use these brushes to make them cleaner, calmer and more comfortable. As the brushes are cow-cleansing, they also reduce the risk of disease associated with barn dirt such as mastitis.

Manual grooming is a time-consuming and labor-intensive task. In addition, the risk of occupational safety is high for inexperienced people. For this reason, mechanical grooming bases have been developed.

4. Mechanical Grooming

Intensive dairy farms provide automated mechanical brushes to provide grooming behavior. Mechanical grooming brushes have many different types for different purposes. Some types of these mechanical brushes contain massage fluids which protect cattle skin health and protect against some parasites. It is designed to be protected against dust and water as it will be used in the barn. The brush is made of long-lasting plastic with softness that will not irritate or injure the animal. The system comprises an L-shaped adjustable support frame for wall or pole mounting, a support spring between the frame, a vertical brush contacting the animal, and an electric motor.

The brush will be mounted in a suitable place in the barn, and when the animal comes to contact the brush itself, the brush will start to rotate slowly, smoothly and comfortably and work in such a way that it can move around the cow or in response to the animal moving the device upwards. The engine of the nail brush will run quietly so that there is no disturbance on the animals. Designed for cattle grooming, this brush system includes a movable motor mounted on a fixed support structure and the motor moves with the brush during operation of the device. The motor is placed vertically on the brush.

Generally, the grooming brush length is maximum 75 cm and it can brush up to the head, neck and body of the animal. This causes deficiencies in the lower parts of the thigh and the lower parts of the abdomen. It may also be caused by problems such as contact or tail fitting to the heat detection pads. But this grooming equipment has been developed for cows to scratch themselves depending on their requirements.

These types of brushes are also proven for beef farm. Similarly, this brush keeps bulls clean and healthy by removing dirt and other parasites, while improving barn hygiene at the same time. All these brushes maintain the optimum massage effect on cow. All these types of brushes are developed for best pressure on the skin to stimulate blood circulation for best performances.

4.1 Stationary Brushes

Stationary brushes consist of a horizontal brush and a vertical brush. Some models have a specific pattern to be adjustable on the size of the cow, which allows the use of cows of different sizes within the herd.

4.2 Rotating Brushes

Rotating cow brushes have a brush that rotates on a horizontal arm attached to a motor which swings left and right (45°). Rotation is activated when the cows move the brush and continue until the arm remains horizontal for a period of time. The rotating cow brush, which can be easily attached to wall or support, starts immediately when touched by a cow. It is driven by a 250 W electric motor, controlled by micro processors. Additionally, it stops automatically in a few seconds after a cow walks away. It immediately stops turning if something gets caught in the brush and reverses direction.

4.3 Swinging Brushes

Swinging brush swings freely in all directions, smoothly up, over and alongside the cow. The rotating

starts when the cow pushes the brush and continues to rotate until it remains vertical for a period of time.

5. Assessment of Brush Usage Level at Farms

The rate of use of brushes of cows in the barn provides some important information on disease, suboptimal microclimate and social problems in herd. On a herd level, brush use could be an indicator of the general welfare and used as a benchmark between herds [5, 6]. The behavioral time budget for cows was 42% lying, 27% walking or standing, 16% feeding, 10% queuing to be milked and 1% of their time drinking, using the brush or being milked [6]. But many factors have effect on brush usage at farm level. Brush usage is affected by overstocking in the barn level. General recommendation is 50 to 60 cows per brush. Breed, lactation number, stage of lactation, dominance or affiliative rank of the cows are effective to brush usage rate. But location of brush, stress level, barn microclimate, and herd social status can be main factor. Because the cow brush usage rate can demonstrate animal welfare, this might give an indication of a change to microclimate of animals that would be difficult to identify by other measures. But still some problems remain at brushes usage at farm level and need more detailed experiments for better performances.

6. Conclusions

It can be said that limited research results published on the grooming brushes usage and the results so far have been positive. When provided, 85 to 100 percent of cows in a herd used brush daily. And brushes improve cows scratching time by six times. And milk production is also improved. Three types of brushes are available on the market which have different size, type and price. These are stationary, rotating and swinging brushes. Many of them are similar to each other but the some of them have more range of motion, allowing it to swing back, forth, and side to side. Overcrowding around the brushes and social dominance issues are very big stress for subordinate cow brush usage rate. Tail chalk (for heat detection) can be rubbed off, and rump-mounted heat-detection devices may be inadvertently activated. The use of a mechanical brush influenced behavior, reducing not active time, while increasing eating time. The consequences of this change in activity require further investigation for better performances and welfare criteria.

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Flood Hazard Mapping at Long Xuyen Quadrangle in 2015 Using Geographic Information System and Remote Sensing Technologies

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Abstract: In recent year, the flooding has occurred with high frequency at LXQ (Long Xuyen Quadrangle) areas of Mekong Delta, Vietnam. It was considered as a major natural disaster which has effects on the physic and spirit in people's life in this area. This research aims to generate a flood hazard map and assess the flood situation at LXQ in 2015. The MNDWI (Modification of Normalized Difference Water Index) extracting from Sentinel-2 image was used to map the flood extent at LXQ during rainy season in 2015. The statistics method estimated correlation coefficient between flooding spatial distribution and hydrological stations on SPSS (Statistical Product and Services Solutions) software. The results showed that the severe flood occurred from August to December in 2015. There were about 47.6% and 28.2% of the total areas that were inundated in October and August, respectively. The correlation between inundated areas and water level at Ha Tien and Chau Doc hydrological stations was 0.73 and 0.65 ($p < 0.01$), respectively. The derived information was very essential and valuable for local managers in making decision on responding and mitigating to the flood disaster.

Key words: Flood distribution, MNDWI, LXQ, correlation coefficient.

1. Introduction

LXQ (Long Xuyen Quadrangle) is the largest rice-producing region in MRD (Mekong River Delta). Above all, rice production in the Mekong Delta has particularly important role in ensuring national food security and contributing positively to exports [1]. However, the face of climate change makes flood in Mekong Delta region in general and in LXQ in particular that has a large variation between in the year of the large flood and the small flood. Water level rise in river caused widespread flooding making serious damage to manufacturing, property and human life in the years of large-scale flooding. The small-scale flooding also brings to a significant damage due to water level in the upstream reduced the amount of water stored in the basin, caused increased salinity intrusion in the dry season and affected agricultural production [2].

Nowadays, remote sensing technology is a powerful tool in management of natural resources to monitor natural phenomenon with the ability to provide data on the vast space, repeated cycle, and remote sensing data become useful for researchers, in managing the implementation of its projects in particular for monitoring of flooding situation [3]. Therefore, the use of remote sensing technology to become more superior with Sentinel-2 data had provided multi-temporal

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image, covering a large space, and been saving time and costs for the research in flood that will be more effective and innovative applications.

For all above reasons, the research of "Flood Hazard Mapping at Long Xuyen Quadrangle in 2015 Using Geographic Information System and Remote Sensing" to assess current flood map in LXQ in 2015, thereby gave timely solutions to limit the damage caused by floods that area basis for management, and flood forecasting to support the managers to have an overview and provide timely solutions for limited damage caused by flood.

2. Study Area

According to Le Sam [4], LXQ is a region belonging to the Mekong Delta including two provinces including Kien Giang, An Giang and one city with Can Tho city, in which about 52% of the areais in An Giang Province, about 46% in Kien Giang Province and the rest in the North Cai San of Vinh Thanh district, Can Tho city (2%). The four edges of LXQ include the Vietnam-Cambodia border, Kien Giang's Gulf, Cai San canal and Hau river. The area of LXQ region is about 489,000 hectares. The terrain is relatively flat with absolute height from 0.4 to 2 m (Fig. 1).

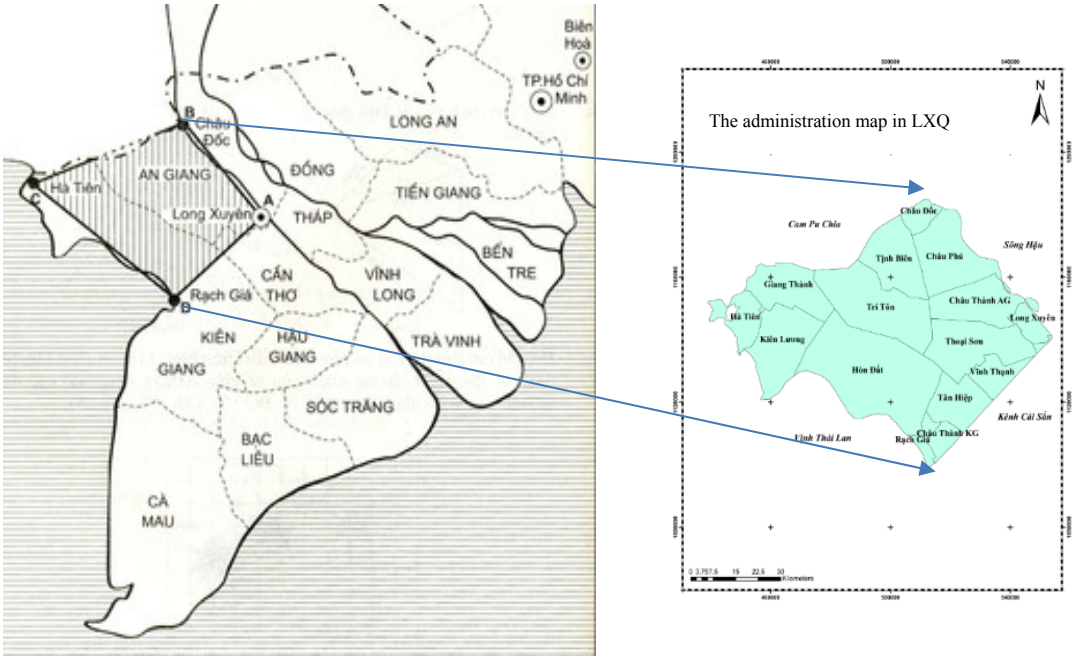

Fig. 1 LXQ's administrative map.

3. Methodology

3.1 Data Collection

3.1.1 Remote Sensing Image

Sentinel-2 images were collected from August to December in 2015 by the ESA (European Space Agency) with the characteristics described in Table 1. The temporal resolution is 12 days and spatial resolutions are 10 m and 20 m. The total scene of Sentinel-2 images was collected by 12 scenes to cover whole study area [5, 6].

Table 1 Sentinel 2A data collection.

Parameters	Sentinel-2
Total image	12 images
Duration	20/08/2015-28/12/2015
Spatial resolution	10 m, 20 m
Temporal resolution	12 days

(Source:https://scihub.copernicus.eu).

3.1.2 Field Data Collection

Water levels data were collected in each month from August to December, 2015 in two hydrology stations of Ha Tien and Chau Doc.

3.2 Satellite Image Processing

Sentinel images were used to integrate between high resolution images (10 m) and low resolution images (20 m) to create the imagery with high resolution (10 m) and multi-spectral imaging.

The MNDWI (Modification of Normalized Difference Water Index) was applied to determine the water index images due to the Eq. (1) [7, 8] as following:

$$\text{MNDWI} = \frac{(Green - MIR)}{(Green + MIR)} \quad (1)$$

in which Green is green band (band 3 of the Sentinel-2); MIR is a middle infrared band (band 8A of the Sentinel-2).

Image classification was implifica used IsoData method of unsupervised classification [9, 10].

3.3 Regresstion Models between Flood Surface and Field Survey Data

Data collection in Ha Tien and Chau Doc stations was from August to December, 2015. Linear regression was applied to assess correlation coefficients (R^2) to demonstrate the relationship between image classification and data collection at hydrological stations.

4. Results and Discussion

4.1 Flood Distribution in LXQ

The results of flood in each month from August to December in 2015 are shown in Fig. 2. The flooded area in August covered at 137,682.64 hectares, accounting for 28.2% of total LXQ area; in September, flooded area was increased to 191,920.05 hectares, accounting for 39.2% of total LXQ area and expanded to 54,237.41 hectares comparing to in August. In October, maximum flooded area reached 232,734.92 hectares with 47.6% of total LXQ area and enlargement of 40,814.87 ha. In November, flood area was covered at 187,682.64 hectares by 38.4% of total LXQ area and decreasing at 45,052.28 hectares compared to last month. In the last month of December, flood area receded considerably 145,776.84 hectares, accounting for 29.8% of total LXQ area that is lower than in November of 41,905.8 hectares. The flooded area variation between the highest flood area in October and the lowest flood area in August is about 95,052.28 ha.

Fig. 2 shows the distribution of flood changes in each month including August, September, October, November and December. In LXQ region, the level of flooding submerged reaching a peak in October and minimum flooded area in August. The reason is that LXQ is a low terrain region or flood zone area in Mekong Delta, when the southwest monsoon starts blowing that is also the rainy season beginning in the basin and cause of flood overflowing in this region.

Flood season usually extends from the beginning of August to the end of December. When the water level on the main river rising, water will flow into river branch or canal and then runoff on the field that is flooded area period increasing. In LXQ, flood is usually extended from the beginning of August to the end of December each year and is divided into three periods. The first period is the beginning of water level in the main river that increases and flows from canals into the field about two months from the beginning of August to the end of September. The next period, flood reaches to the peak level depend on water volume in the upstream coming sooner or later in years and flood peak appeared almost in October in years. The final period was decreased water level and receded gradually around two months from November to December (Fig. 2).

4.2 Flooded Changes Areas in LXQ

The flood area and non-flood area were determined with image classification and showed flood area changes in LXQ in 2015. In August, flood area started to cover around 137,682.64 hectares, accounting for 28.2% of the LXQ area that is the lowest flood area covering in this month. In September, flooded area increased gradually and reached to 191,920.05

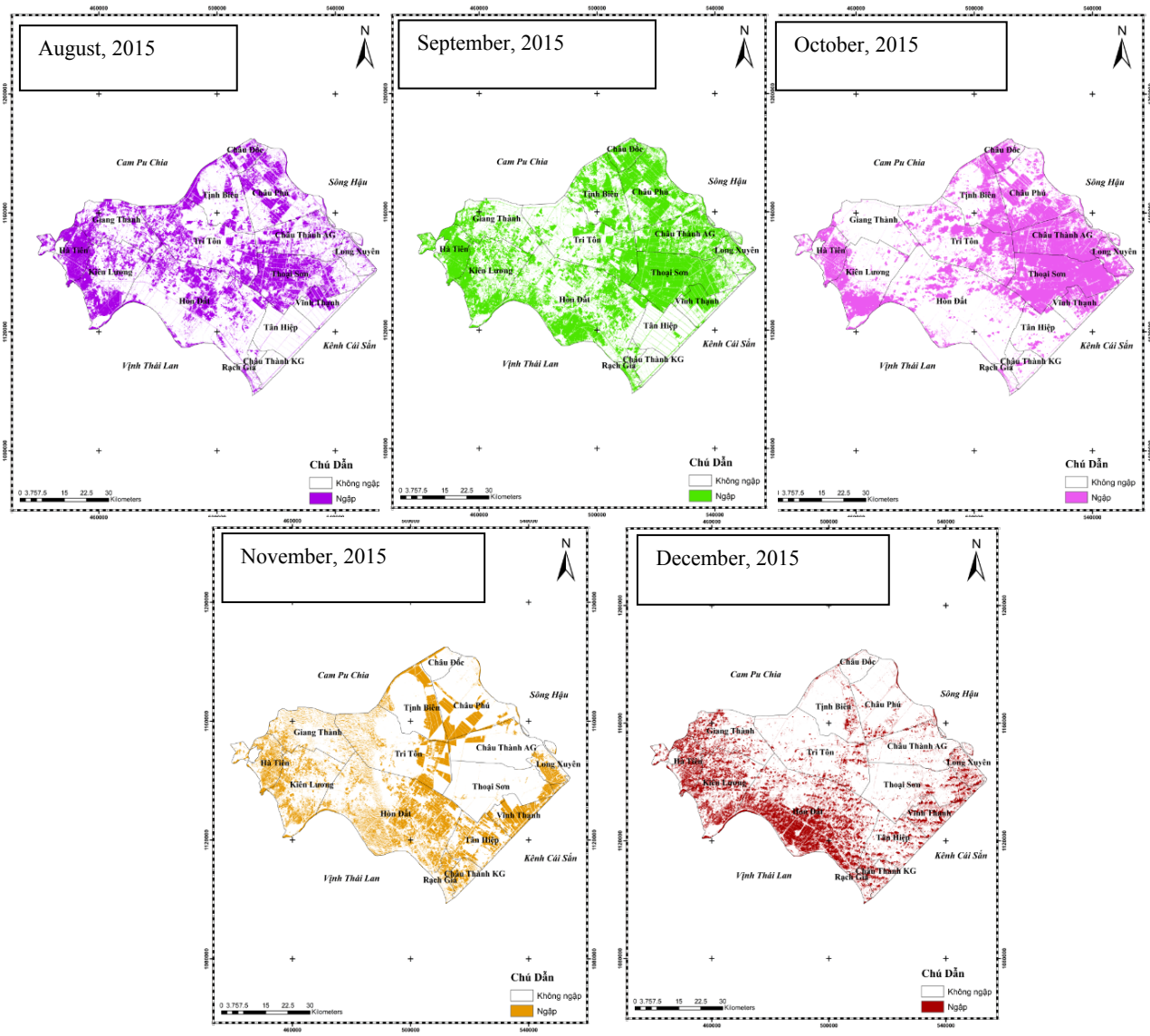

Fig. 2 Flood maps distribution from August to December 2015 in LXQ.

hectares with 39.2% of the LXQ area. Peak flood began in October with an area going up dramatically to 232,734.92 hectares, occupying 47.6% of the LXQ area. From November to December, flood significantly reduced compare to the flood peak period with flooded area turning into 187,682.64 ha (38.4%) and 145,776.84 ha (29.8%). Flooding progress in LXQ coincides with the rainy season and flood in the study site appears in certain periods with a few changes (Fig. 3).

Fig. 3 shows the flood of LXQ began appearing in August, flood peaking in October and flood ending in December in 2015. There are five months in the upstream districts to cover by flood area, then extending to the neighboring districts. The flooded area starts in August and increases in September approximately corresponding to the beginning of the flood season in LXQ. Flood area reaches a peak in October and then decreasing and ending into two months of November and December in year. Fig. 2 provides an overview of surface water area changes during rainy season that is a basis to determine flood movements as well as water level in 2015.

Moreover, Fig. 3 shows surfacce water area changes in three provinces including An Giang, Kien

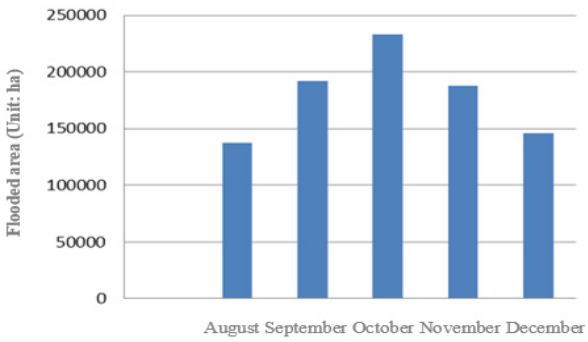

Fig. 3 Flooding area in the LXQ region in five months from August to December.

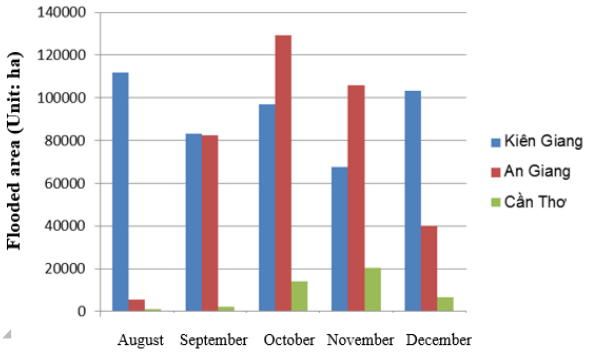

Fig. 4 The fluctuation of flooded area in three provinces belonging to LXQ.

Giang and Can Tho in LXQ belong to each province area covering in the study site. However, flood fluctuation follows a general rule, surface water area began to rise in August, September and peaked at a certain time in October then decreased in the last two months in November and December.

4.3 Long-Period Fluctuations in Moonsoon Floods in the LXQ

Fig. 4 shows flood covering in An Giang province with the largest flood areas distributed in the LXQ. Flood was appearing in August and September and peaked in October and the flood water surface receded gradually in November, then fell sharply in December. The causes of flooding occurred appearing in the upstream area thus most of the districts in An Giang province were affected first, then overflowed to any direction and expanded corridor districts surrounding in Kien Giang and Can Tho provinces where as low terrain area.

Besides, Fig. 4 also shows the flood peaks in Kien Giang province in August, falls down in September, and continues to increase in October and then decreases gradually in November and extends a bit in December. Kien Giang province lies on the border of the West Sea and managed by the sluice gates along coastal area, thus flood drainage capacity has a trouble to runoff in this region at the end of flooding periods.

In Can Tho city with only Vinh Thanh district, flood affected almost primarily in November. The reason of Vinh Thanh is the last district in the east of LXQ, thus flood reaches later then and low flood covering in this region (Fig. 4).

4.4 Comparing Flood Situation and Filed Data

In the rainy season, water surface level in the river rises exceeding a terrain leading to overflowing from rivers or canals into the field. The flood area is increasing with the overflow from the river, the water level will be higher and higher on the field. The study conducted the correlation between the flood area in Kien Giang and An Giang provinces to classify images Sentinel-2 and water level data to be recorded from hydrological stations of Ha Tien and Chau Doc. Hydrological data monitoring were collected in rainy season period from August to December in 2015. The correlation between the flooded area in Kien Giang and An Giang provinces with water levels of hydrological data is shown specifically in Fig. 5.

The results show the positive correlation between flood areas and hydrological data at two stations of Ha Tien and Chau Doc with high correlation coefficients of 0.731 and 0.651, respectively. The result provides a better overview current flood covering in LXQ in both spatial and temporal variability of flood seasonality in 2015. From the comparable results, flood monitoring in LXQ in the year of 2015 using satellite imagery Sentinel-2 has a significant statistics.

5. Discussion

The LXQ is a part of the Mekong Delta located at

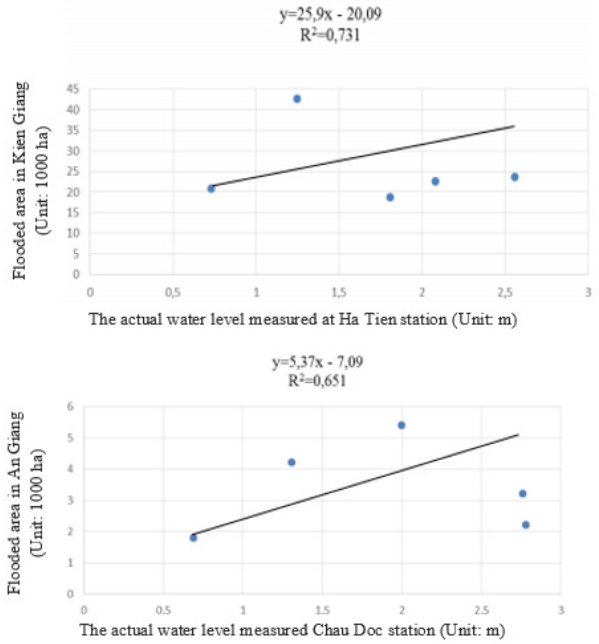

Fig. 5 Correlation coefficients between the flooded area and hydrological stations.

the farthest downstream end of the Mekong river basin. It is a flat and low-lying area of 489 thousand ha and occupies about 20% of the whole Mekong Delta basin, Vietnam [11]. The tidal effects on the flooding in the LXQ are complicated and caused long lasting inundation at the end of the flood season. Flooding occurs with most severe damage caused by water disasters or climate related disasters to impact most of the population living in areas susceptible to flooding [12]. In 2000, the dangerous floods were concentrated in the regions of the "Plain of Reeds" and the "LXQ" [13, 14]. Local residents living in the upstream section have great experiences to eliminate negative impacts and earn the most benefits from such natural events. In contrast, local residents living in downstream section of the delta are not used to tidal-induced floods leading to negative impacts (e.g., damages of the agriculture and aquaculture) [12], leading to negative impacts on the local livelihood [15, 16]. Thus, a dense canal system has been created in flood-prone areas to efficiently drain flood waters from the LXQ and the PoR (Plains of Reed) to the West Sea (Gulf of Thailand) and to the Vam Co Rivers, respectively and the high dyke system is intended to reduce local natural flood hazards [17]. The high dykes system in the LXQ can reduce the discharge of the Song Tien, diverting around 7% of the total volume to Song Hau and the inundation periods are slightly shorter due to flood withdraw to the West Sea [18].

6. Conclusion

This research created spatial and temporal distribution of flood using Sentinel-2 image data for an overview of the current flood distribution in LXQ in 2015. The spatial progress of flood during five months from August to December in 2015 shows the flood peak discharging in October and ending in December in LXQ region and the current flood maps in each month have been established using Sentinel-2. Flood almost affected two provinces of An Giang and Kien Giang and one city of Can Tho city which the districts in upstream including Chau Phu and Tinh Bien (An Giang Province); Ha Tien and Hon Dat (Kien Giang Province) and only Vinh Thanh district (Can Tho city) covered by flooding and affected area in those regions. The results of flood area precision have high correlation based on a comparison between the flooded area and water levels at hydrological stations of Ha Tien and Chau Doc with R^2 equal 0.731 and 0.651, respectively.

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