

IMPACTS OF URBANIZATION AND DROUGHT ON RICE SURFACE CHANGE: CASE STUDY GIANH RIVER ESTUARY, VIETNAM

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Abstract. Landscape changes, especially the rice landscape in a context of urban growth and drought, is a current issue in Vietnam, particularly in coastal areas at the origin of the water resource pressure. A human geography approach, combined with the study of physical geography, helps to understand the landscape construction at the fourteen communes in the mouth of the Gianh River (Quang Binh Province, Central Vietnam) and analyze the relationships between the changes of rice landscape and urbanization. It highlights the impacts of drought on agricultural activities, as well as helping to understand the effects of changing landscapes on water resources. In the study area, the inhabitants work mainly in agricultural activities that depend on the rice landscape and the water resource to feed their families and produce an income. However, since the Doi Moi policy in 1986, economic liberalization and the opening of Vietnam have led to a change in the soil's occupation, particularly within the agricultural zone. This change has led to difficulties within agricultural activity and has increased the impacts of the drought phenomenon, particularly in decreased precipitation and temperature increase. Such issues should guide the orientations of development policies along the river and in the mouth in

particular. This is why, in this article, drought maps are produced to follow this problem and to help develop irrigation networks to ensure food security.

Key words: agricultural, drought, landscape, urban, Gianh river, Vietnam

1. Introduction

Vietnam is an agricultural country. From river mouths to plains and mountain regions' terraces, irrigated rice cultivation is an important place for the Vietnamese (Belton *et al.*, 2011) to ensure food security and family revenue. However, since the Doi moi policy (renovation policy) launched in 1986, the country has engaged in a transitional process, leading to the development and the growth of urbanization becoming stronger (Petrișor *et al.*, 2020). Like many emerging countries, in Vietnam, there is significant pressure upon land between actors, especially upon agriculture (Azadi *et al.*, 2010). The urban and demographic growth, new buildings and infrastructure sometimes replace rice landscapes (Nguyen *et al.*, 2018). This highlights there is competition, in this study the competition for water resources, which is exacerbated by rural and urban spaces (Vörösmarty *et al.*, 2000; Hamidreza, 2018; Isfanescu, 2010). Apart from the impacts of urban growth, Bakker *et al.* (2009) highlighted that natural disasters such as flood or drought are considered important factors to modify rice landscapes.

To respond to this larger problem, the Vietnamese government is witnessing a formidable scientific, legal and technical mobilization such as the construction of irrigation networks, providing mechanization tools, etc. to cover loss and damage due to natural

disasters like drought. However, in the context of climate change, these measures are not yet sufficient to reduce the impacts of drought and urbanization on agricultural activities. Therefore, the determinations of the area with high drought are necessary to plan sustainable rural territories.

With the development of spatial data with the data sharing policies of agencies like NASA and remote sensing technology, they provide a reliable solution to analyze changes in the rice landscape from a local to a global scale. Rojas *et al.* (2011) used the Vegetation Health Index (VHI) from the Advanced Very High Resolution Radiometer (AVHRR) and NDVI to calculate droughts in Africa. Raksapatcharawong *et al.* (2020) were applied rainfall, land surface temperature (LST), and normalized difference vegetation index/leaf area index (NDVI/LAI) satellite products to assess the impacts of droughts on the rice cultivation. Mottaleb *et al.* (2015) used Moderate Resolution Imaging Spectroradiometer (MODIS) data to estimate agricultural damage due to droughts in Bangladesh.

In the Gianh River's mouth, the question of landscape change is current, but also a source of controversy. According to the Department of Agriculture of Quang Binh Province, from 2000 to 2013, the rhythm of rice landscape decreased by 1.5% per year. However, there is little research on this problem. Therefore,

this study aims to understand the situation of landscape change and its consequences, alongside helping decision-makers measure and monitor droughts in the agricultural zone, whilst understanding the economic actors that pressure water resources to guarantee growth. In this study, we chose fourteen municipality in the Gianh River's mouth where there are different types of landscape and differences in rhythm of rice landscape change to consider two questions: what are the factors of rice landscape transformation? And what are the consequences of changing the rice landscape?

Firstly, a diagnosis of the territory will be made to understand the landscape downstream of the river. We will then present how landscape changes in the study area are related to economic and social policy, mainly population growth and urbanization. Then, we will explore the modifications of landscapes caused by droughts. Finally, we will discuss the evolution of the landscape the challenges it faces.

2. Study areas and methods

2.1. Study areas

The fourteen municipality, in the mouth of the Gianh river, is located downstream of its catchment area, which has an area of 4 680 km². The mouth of the Gianh river was characterized by a rapid decline of agricultural land in the 1989-2013 period, with a rate of about 0.6% per year. This phenomenon occurs especially since the Doi Moi policy launch in 1986, which represented an interesting example to evaluate the effect of population dynamics and climate change on landscapes.

Due to its advantageous location for servicing inland enclave provinces and the development of an access road to Laos, the Vietnamese authorities have ambitious urban development projects for the delta from 2008 to 2020: 23 projects have to be developed in the transport sector, infrastructure services, 21 trade and service projects such as commercial center, tourism center, 40 public infrastructure projects and several tourism projects in the delta as the construction of the ecotourism area on the Gianh River, on an area of 317 759 ha. Particularly, the rice surface in Quang Phuc commune will be deleted and replaced by the urban surface, and new seaside tourism project will be built on the beach in Quang Thuan town. At the same time, demographic and urban growth have come. According to the master plan of Quang Binh with vision up to 2030, the Gianh River's mouth will be chosen to be the center of the North of Quang Binh Province.

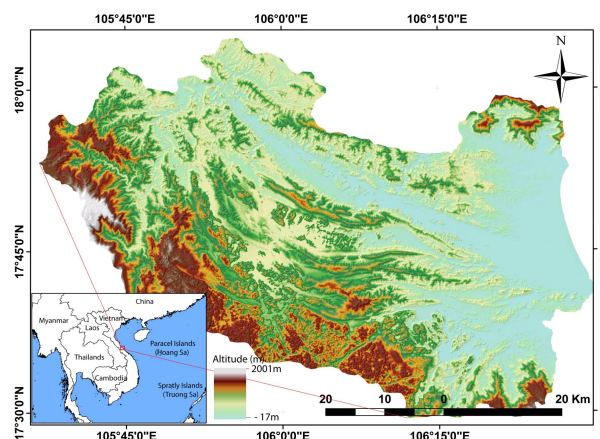


Fig. 1. Study area.

2.2. Methodologies

To answer the research questions raised previously, we applied two processes with different methodologies.

Firstly related to remote sensing and GIS which is considered to be one of

the most popular methods for analyzing land cover and land uses changes (Tache *et al.*, 2018), the Landsat satellite images in 1989, 2003 and 2013 are used in this article. The classification comparison method (Liu and Zhou, 2004; Bui *et al.*, 2019) was chosen to detect changes in land use/land cover. The principle of this method is based on the classification of two scenes acquired on different dates. It first assigns classes and then detects the changes. This method can provide detailed information about changes and prepare changes maps (Deng *et al.*, 2008; Eskandari and Moradi, 2020). To better separate objects and reduce confusion, the pseudo-oriented object-oriented classification (PCA, NDVI) approach was applied using the Envi software (Petrișor *et al.*, 2020).

Thanks also to remote sensing, to calculate the indices of drought, we must accomplish two steps: The first step was to use the MOD11A2 and MOD09A1 products to create values Normalized Difference vegetation index (NDVI) and Surface Temperature (LST) values. Each of these two products provides an image every 8 days at 500 m grid resolution in the sinusoidal projection. So we acquired four images a month, from March to May. The results were a series of 16 images per year. Step 2 was data processing using the Envi software to calculate NDVI, LST and TDVI. The Transformed Difference Vegetation Index (TDVI) method was used to monitor and measure the intensity of drought (Jiao *et al.*, 2019; Chen *et al.*, 2020; Schwarz *et al.*, 2020; Nguyen *et al.*, 2019).

In second step: Rice landscapes in fourteen communes within the mouth

of the Gianh River are analyzed from three field missions in 2015, 2016 and 2017 with the methodology of sociology (structured interviews and semi-structured interviews). Two major issues are addressed: the natural factor with topography and hydrological networks, and the human factor with habitat, land use and infrastructure. In addition, we conducted questionnaires in 8 communes. This included 140 farmers (mainly along the Gianh River) and interviews with mayors in areas undergoing major rice landscape changes due to urban growth and droughts. The objectives of this work are:

- Assessing the impact of urbanization on the future of agrarian structures (to better define the dynamics of spatial and social changes).
- Build a typology of crops, agricultural and fish production systems downstream of the Gianh River.
- Understand the impact of natural disasters on agriculture and its ability to fight against them.
- To know the human development on the Gianh river to reduce their effects of droughts and to develop agriculture.

3. Results

3.1. The landscapes of the mouth of the Gianh River: A diagnosis of the territory

The European Landscape Convention states that "landscape refers to a part of territory as perceived by the people, the character of which results from the action of natural and/or human factors and their interrelations" (Council of Europe, 2000). According to Burel and Bauray (2003) "landscape is a catalyst between nature and society based on a

portion of the material space that exists as a structure as well as an ecosystem, and therefore independently of perception". A landscape is made up of several components, while land use is the most important component because of the anthropogenic activity, the structure of the vegetation.

The type of landscape below the Gianh River is built according to the topography, human activity and planning policies of the country: urban landscape, rice landscape, fish farm landscape and forest landscape (Fig. 2).

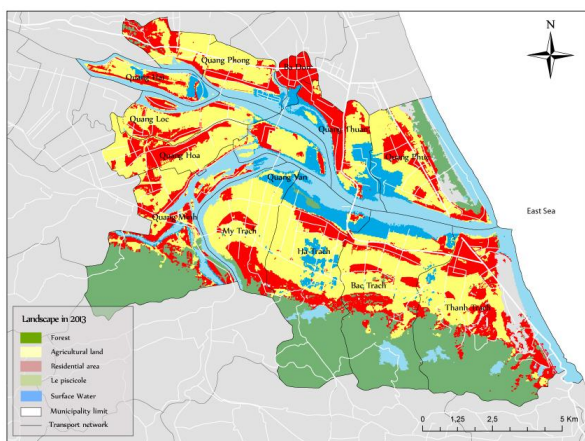


Fig. 2. The study area and land-use in the study area.

However, landscapes are traditionally shared between two main functions: habitats and rice production. Traditional rice cultivation is located in the lowlands (about 2 m), close to the hydrographic network where irrigation systems and canals irrigate. Whilst the uplands (about 5 m) are intended for urbanization. Villagers lands divide by small. Natural and production forests cover the hills, where dams have also been constructed. South of the mouth (Bo Trach district), there are two large dam lakes, Vuc Sanh and Dong Ran, to irrigate rice crops during the dry season. The control and use of water was a fundamental condition for the

continued expansion of a viable agrarian economy thus leading to greater control of water, enabling both maintenance and the development of this economy alongside landscape creation. Through the processes of economic and urban growth, there are significant changes throughout both functions. This is due to rice landscapes being fragmented and located along the major riverbed, concentrating around the villages. Village expansion is detrimental to these farmlands (Malaque and Yokohari, 2007; Ha *et al.*, 2020).

During our flight, we discovered the main features of the landscapes of the region. We first discern the relief, then reveal the plant cover, the land use. Flat and sandy areas distinguish the coastal zone landscapes. The shoreline sits at the edge of the sea, which is a wide about 0.5 to 1 km in area. Here resides the town of Quang Phuc where covered by the filao to fight the typhoon. Since the fieldwork in 2017, this landscape has transformed in favour of a "luxury landscape", a specific type of landscape development to promote and encourage tourism in coming years. The project will see an increase in urban development, thus leading to increasing tourist numbers and a reduction in area available for rice farming, a significant factor in modifying the rice landscape. Although many villages are in close proximity to the sea, they are very densely populated. The villages are located between the rice fields and the hills, stretching along the paths and 1A national roads. These cross the communes and represent an important axis of communication. The houses sit around 1-2 metres above the rice fields. Within these zones, there is a fishing,

port. The geographical situation is favorable for economic and urban development, and therefore urban surfaces have increased in order to answer the needs of the inhabitants and the seaside tourists.

As a result, this area represents a specific example of competition for space between urbanization and various land-use activities within Vietnam. This is the major problem that drives the debate and directs new research. This is not a simple debate, but it is a future debate that should lead to careful management and organization of the territory.

Moving from the sea to the hinterland, we can meet fish landscape. They are present especially along the river thanks to the rich hydrological network. Low-lying hills (50 meters above sea level) can be found in the right bank of the Gianh River. These are covered by natural forests and reservoirs. Irrigation networks and canals are developed from the hydrological networks and reservoirs to counter droughts and develop agriculture. They play an integral part in the rice landscape fragmentation. In addition, the villages, located at the top of the hills, are interconnected by numerous hamlets and isolated houses. The plains that lie between 0 and 10 meters above the sea level are approximately 10 km wide. This is suitable for the installation of houses and rice plantations. These landscapes are heavily modified, especially between the rice, maize and urban landscaped due to the country's economic development strategy and the effects of natural disasters like droughts. Therefore role of irrigation network development is extremely

important in constructing the landscapes of this region.

3.2. The important role of rice growing in the construction of landscapes in the mouth of the Gianh River

Vietnam is a large agricultural country whose economy relies on agriculture as a main source of output (Pham *et al.*, 2019). According the General Statistics Office of Vietnam in 2016, since Doi Moi until 2016, Vietnam's agricultural sector has always contributed over 15% of the economy's GDP. The Gianh River watershed in central Quang Binh province is one of the agricultural granaries in the centre of the country. This area is mostly devoted to rice cultivation.

Thanks to the hydrological potential of the watershed, well fed by seasonal rainfall, rice cultivation is a real asset; historically becoming a key agricultural component of Southeast Asia. The watershed has a considerable water resource. According the Department of Natural Resources and the Environment, within the watershed, there are 57 reservoirs with a stored water volume of 153.023 million m³, 8 billion m³ of surface water and 300 000 m³ of groundwater. The average annual rainfall exceeds 2 500 mm in mountainous areas and 1 500 mm in the mouth; this rainfall is concentrated between September and November. However, these resources do not correspond with when rice farming needs them most. As a result, various agricultural landscapes within the area are modified. At the mouth of the Gianh River, 10 pumping stations and 11 water reservoirs represent approximately 4 660 ha of irrigation area. This represents 30% of the utilized agricultural area (14 218 ha). In recent years, agriculture has

faced severe droughts which contributes to many difficulties for agricultural development.

After conducting field observations and interviews with the locals, we have been able to identify two types of land: Land with two rice crops (one wet and one dry crop) and that with only a single crop (spring rice). Why are there two types of land downstream? On the left bank, where the fields have a single crop (communes of Quang Phuc and Quang Thuan), urbanization, industrial activity, and population density has increased. This has led to further competition for water resources, in an area of declining rainfall. According to the Department of Natural Resources and Environment, rainfall decreased from 2 908 to 1 613 mm/year between 2010 and 2015. The difference between the two measurements are due to the location of plots in relation to equipment, particularly those used for irrigation. The plots on the right bank are close to dam lakes, thus facilitating irrigation and the presence of several crops. Yet the land on the left bank has little or no facilities for their irrigation. This exemplifies the importance of hydrological management upon the rice landscape.

Fig. 3 shows the landscape in the study area. Rice production and urbanisation has played an important role within this landscape. Since the 1986 with the Doi Moi policy of the country which caused the pressure of land, especially the agricultural surface.

In Vietnam, the nation has experienced widespread technology transfers, including; containment, irrigation and livestock farming techniques that have

allowed intensive rice cultivation in certain areas. The development of hydraulic networks has been prioritised to increase agricultural production. However, is it also a factor in creating the rice landscape in this study area? The rice landscape downstream is marked by irrigation schemes and the seasonal evolution of rice plots. To understand landscape changes today, the presentation of old landscapes is necessary. Before modernised irrigation, farmers dug canals in the middle of fields. Rivers were connected with artificial water storage systems (small reservoirs). At this time, construction systems were not developed due to the country's finances. There was not a sufficient budget to construct concrete irrigation systems. Therefore, farmers had two main tools at their disposal to raise water levels in Northern Vietnam: the basket scoop and the tripod scoop. Throughout the country and in the mouth of the Gianh River, the colonial administration has improved the conditions of agricultural water supplies in an attempt to double the yearly crop and increase agricultural production. This would therefore ensure food security in the watershed. In the context of the generalized embargo of the capitalist countries, Vietnam has tried to develop rice farming for its food independence.

Before 1953, the rice plots were large in size. However, after land reform and land becoming Landed property, they soon became smaller. After 1988, the country experienced its first land law. In the river mouth, the plots are small with a maximum surface area of 200 m², 500 m². Irrigation networks were then built to irrigate these lands (Nguyen *et al.*, 2018).

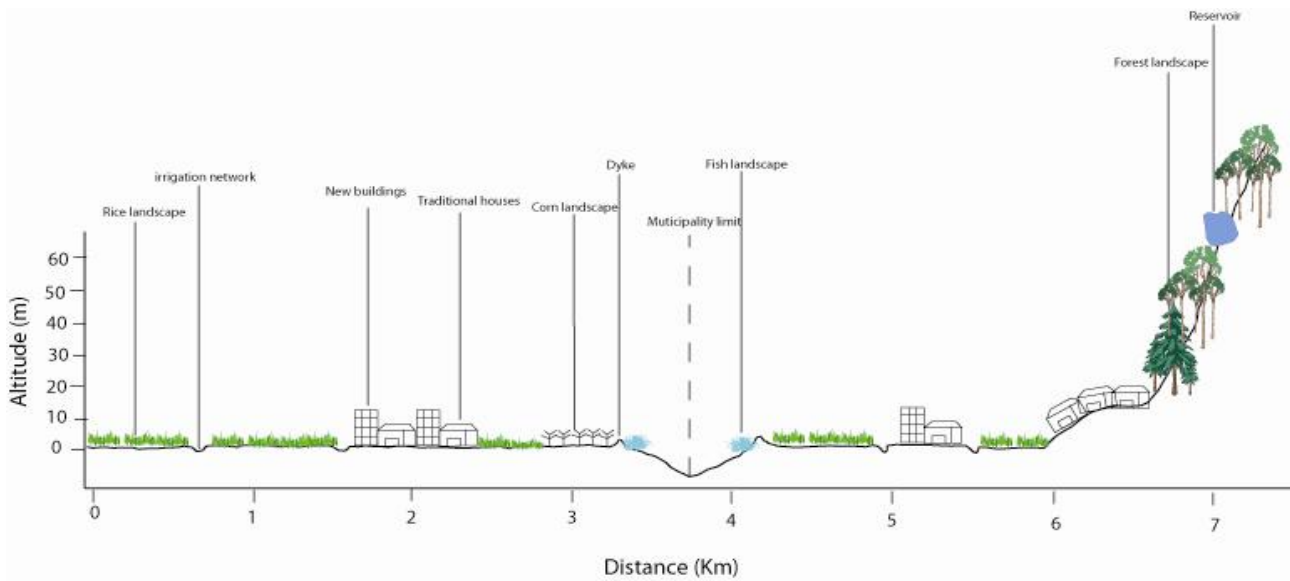


Fig. 3. Landscape section at the mouth of the Gianh River in 2013.

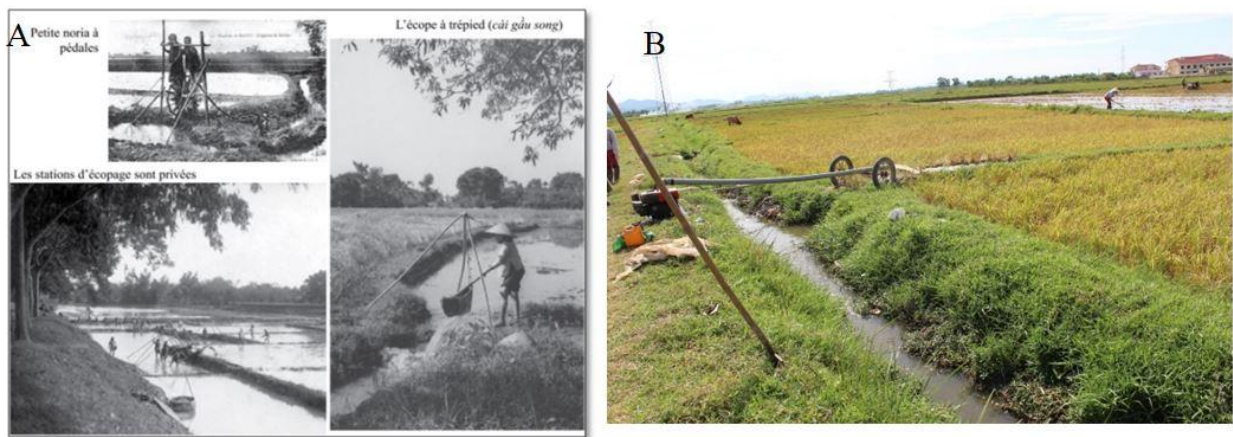


Fig. 4. The evolution of the irrigation network in the mouth of the Gianh River. Fig. 4A (to the left) shows the two main tools for raising water in the entire region of northern Vietnam: the basket scoop (cai gau dai) and the tripod scoop (cai gau song). Figure 4B (to the right) shows the concrete canal systems that connect directly to the plot to irrigate.

As a result of collectivisation policy in the 1960s, major hydraulic works were undertaken. This includes the installation of large irrigation schemes to facilitate watering and drainage within the bins (Fontenelle, 2004). Rice areas were therefore extended, resulting in a changed landscape. However, due to lack of maintenance and an aged design, these irrigation networks have degraded and often fail to meet farmers' needs when a drought occurs.

The pressure associated with urbanisation and the further destruction of the rice landscape exacerbates this. These factors made irrigation and water distribution systems a great concern to the Vietnamese government whilst developing rice cultivation (Khazaei *et al.*, 2004; Rashid *et al.*, 2018). To address this problem, irrigation systems were (including in the mouth of the Gianh River) were constructed with concrete and are fed by reservoirs in the hills.

The development of reservoirs is essential for controlling irrigation water throughout the seasons. These are then able to serve various agricultural activities whilst limiting the risk of flooding during the rainy season. According the Agriculture Department, since 2005, the Provinces People's Committee has built 25 new water reservoirs and a pumping station. In 2020, the People's Committee of Quang Binh Province set aside a total budget of 33 million euros to develop irrigation and water supply networks to 25 552 hectares of land. This being 82% of the area under cultivation in the mouth of the Gianh River.

Fig. 5 focuses on the Vuc Sanh Reservoir, it was built in 2013 and is constructed from concrete. The reservoir is located in the Bac Trach Commune (in the river mouth) and has a storage capacity of 3.2 million m³ with a surface area of 4.5 km². Due to the irrigation networks, water from the reservoirs makes its way to the rice field plains.



Fig. 5. The Vuc Sanh Reservoir in the municipality of Ha Trach.

These "water landscapes" have been regularly modified to meet irrigation requirements needed for the development of agriculture and the necessities of demographic increase.

3.3. The transformations of rice landscapes: from the physical factor to the human factor

Changing land-use is an important aspect of transformations that have taken place in areas of historic human occupation (DeFries *et al.*, 2004; Bonilla-Moheno *et al.*, 2012). The conversion of agricultural land, woodland and wetland into urban and industrial land has risen dramatically worldwide in the last few decades (Li *et al.*, 2015). Understanding the driving forces behind land use change is a crucial issue in land change science (Turner *et al.*, 2007), socio-economic science and environmental science because land-use change is a process related to the interaction between natural and economic factors. This takes place across time and space under several human-environmental conditions (Huynh *et al.*, 2019; Lambin *et al.*, 2001). For example, the evolution of the rice surface is particularly influenced by urban growth policy, demography and culture, etc. (Khanal and Watanabe, 2006; Rajpar *et al.*, 2019). Thus, observing the change in rice landscape helps explain the various specific factors that lead to present day landscape transformations.

In the this study, we present the case of the mouth of the River Gianh. The graph below shows landscape evolution between 1989 and 2013 in the mouth of Gianh River.

Fig. 6 shows the effects of urbanisation upon forests, orchards and areas of rice.

There has been a minimal decline in agricultural land; however, rice paddies are replacing orchard areas, leading to a change in the rice landscape. Our

results show that areas occupied by rice cultivation are decreasing, whilst urban surfaces have increased between 1989 and 2013. At Gianh's mouth, there are several reasons leading to the rice landscape change.

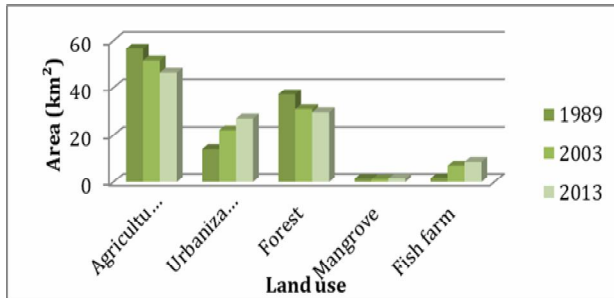


Fig. 6. Land cover in the mouth of the Gianh River in area from 1989 to 2013.

First of all, amongst the physical factors, topography is a determining factor in on-going land use changes. Urban expansion in the lowlands along the Gianh River has been hampered by the scarcity of suitable building land. This is due to the narrowness of the basin, framed by slopes which hinders construction. The slopes upstream are large but the width of the valley is small at 2 km. Meanwhile, the area downstream has a smaller slope, ranging from 0-5° with a 10km-width. In terms of development and construction projects, this explains the focus on the mouth of the river.

The land law appears a decisive element in ensuring the current landscape status. So why is the rice landscape regressing, when the law forbids its modification? In accordance with the 2003 Land Law, owners are prohibited from changing the type of land use. This question remains a sensitive issue due to decentralisation and planning. In fact, if the Vietnamese government approves provincial-level development plans, the province can

modify agricultural land to create urban, industrial and commercial areas. This will facilitate the removal of important agricultural land, despite land legislation. From this analysis, an obvious answer could be the attitude of the Vietnamese government prioritising the development of the economy and industry whilst supporting urbanisation. In doing so, the country has become more industrial than agricultural, according to the study by Li Fei (2015) in developing countries, rapid population growth, poverty and the economic situation are the main driving forces, explaining rice landscape modification.

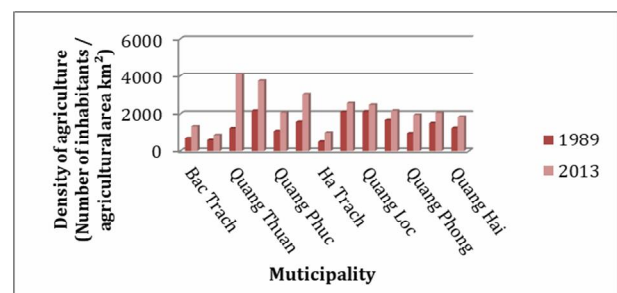


Fig. 7. Population trends in fourteen municipalities in the study area from 1989 to 2013.

The double pressure of rapid urbanisation and rapid population growth has wreaked havoc on farmland. In the case study area, the dynamics of rice landscape-growing areas are linked to demographic pressure, the social economy and the policies implemented alongside urbanisation which has contributed to landscape transformation at a spectacular pace over a few years (Meyer and Turner, 1992). Agriculture then becomes an issue in the face of urban development on agricultural surfaces. Downstream, an increasing population causes pressure on agricultural surfaces. According to Li Fei (2015), the rice landscape is less modified when population density is low and vice versa. Fig. 7 shows the population density of

agricultural land from 1989 to 2013: population density increases in all communes during this period, especially in Quang Thuan, Quang Phuc and Thanh Trach municipality. This is exemplified by infrastructural development and urbanization.

Population growth and favorable geographical location (in proximity with Dong Hoi-capital of Quang Binh province, and beaches for tourism development) has led to urban extension and a decrease of agricultural land. According to land use plan of Quang Binh province, by 2030, the rice landscape will be replaced by non-agricultural land. This situation will be occurred with total area of Quang Thuan and a part of area of Quang Phuc municipalitie by 2030. In

addition, according to estimations made by the Department of Construction of Quang Binh province, population growth in the mouth of the Gianh River is predicted to increase by 60%-70% in the period between 2010 and 2030. As a result of the Urbanization growth policy of the People's Committee of the province, it is projected that the total rice area in the communes of Quang Thuan and Quang Phuc will disappear by 2030.

From the field mission in 2017, we observed that rice plots are now grouped together along the road. According to the Director of Agriculture's office in Ba Don City, this change is to facilitate rice farming. However, we questioned whether this is really just the planning of urbanisation?

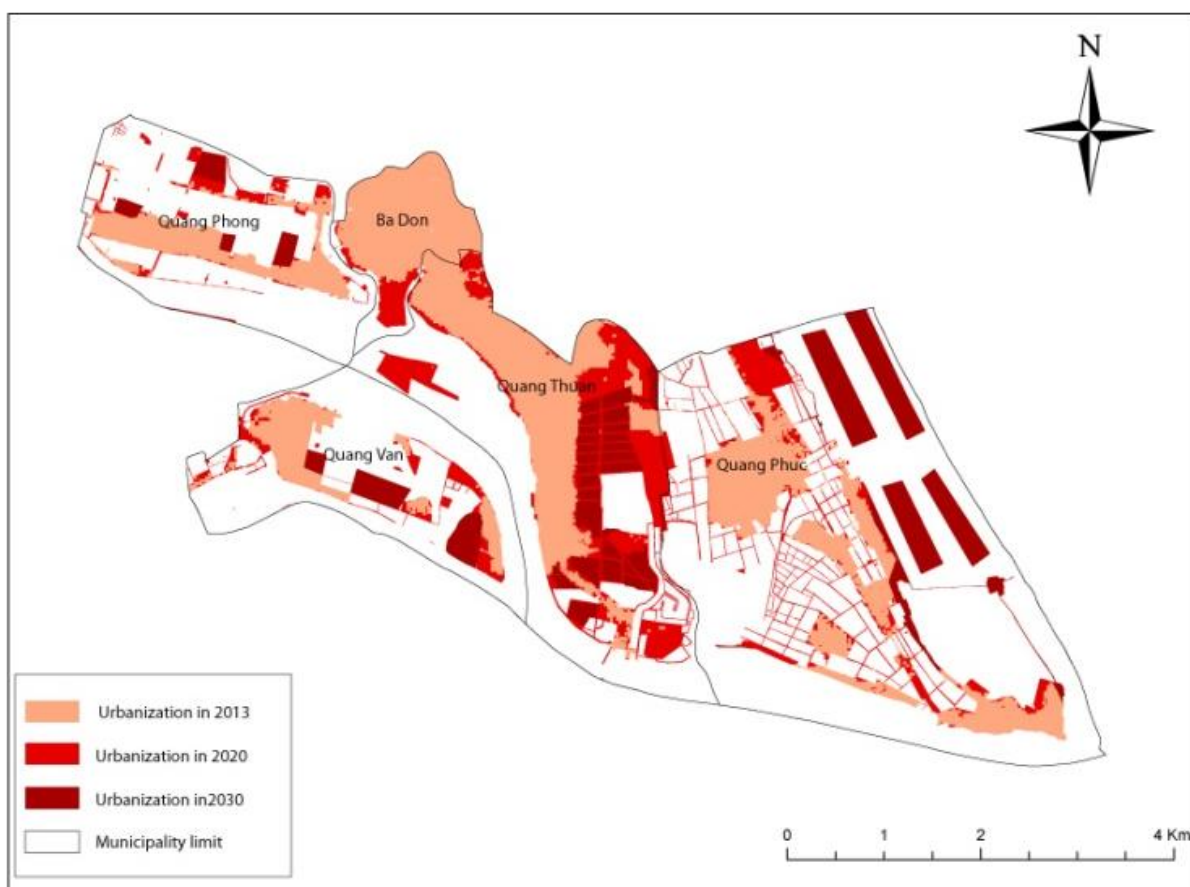


Fig. 8. Urbanization projects by 2020 and 2030.

Amongst the questions we asked in field interviews, one focused on urbanization: what are the changes in the built-up surface of your family? During the field mission in 2015, we interviewed 140 people living in the communes in the mouth of the Gianh River.

Nobody noted a decrease in built-up areas. However, 50 people (35.7%) responded that built-up areas of their families have increased. This is due to the increase in family size and improved quality of life, ultimately leading to strong demand for construction. 87 people (62.1%) said that built-up areas had remained the same. According to farmers, rice paddies have declined as the Provinces People's Committee has built new roads to meet the needs of locals and trade. Three people said surfaces had remained the same.

According to the directors of the Department of Agriculture and Rural Development of Quang Binh Province: "Urbanization and industry have impacted agriculture, reducing agricultural area over the years while competing for water resources. Labour requirements affect local agriculture. But it is a policy of economic and social development of the province".

The change in the rice landscape is not only a consequence of urbanization and industry, but is also linked to the impacts of natural disasters such as droughts.

3.4. Droughts in the rice landscape of the mouth of the Gianh River: one of the important phenomena affecting rice landscapes

The consequences of droughts are amongst the factors that affect the change in rice landscapes. Droughts have intensified in the study area. This

is not only due to a lack of rainfall, but also the difficulty of irrigation due to a lack of water in the river (Panaitescu *et al.*, 2014). In 20 years between 1980 and 2000, precipitation levels have decreased more than 100 mm during the dry season (from January to March). Whilst the figure sits at 70 mm between 2000 and 2016, the river level drops around 10 cm during the three months of the dry season, causing many difficulties with irrigation.

Fig. 9 represents the spatial evolution of drought from 2010 to 2016, with a huge variation. In which, the years of 2010, 2011 and 2013 have a higher intensity of change than other years. Besides, there is a specific distribution of drought between the riversides. The right bank of the river experiences more devastating droughts than the left side.

The area suffering extreme drought covered a total area of 7% in 2016 and 8% in 2014, whilst the figures for 2012 and 2010 are 1.14% and 9% respectively. 2013 and 2011 saw an anomaly, recording levels of 29% and 41% respectively. This is due to a decrease in precipitation (around 100 mm difference compared to the years of 2010, 2014 and 2016). The surface area affected by moderate droughts affected 39% in 2016, 36% in 2014, 39% in 2013, 8% in 2012, 54% in 2011 and 68% in 2010. This is explained through directive interviews with the population. Drought is one of the most damaging factors to agriculture and food security in the region. According to the survey, 124 people (88.6%) responded yes to the question: "Is your farmland affected by a drought?". While, 11.4% people said "no" because their agriculture land nears the reservoir. Every year, during the dry season, the drought is becoming more

serious, particularly in 2011 and 2013. Therefore, rice farming is becoming more and more difficult (field results, 2016).

Depending on the the available resources, the water needs and the drought threshold, we can distinguish two types of drought that continue to affect the mouth of the Gianh River.

The first is the typical annual drought, and the other a more severe drought. The usual drought is considered non-hazardous and water requirements are almost always assured. Farmers are able to adapt through irrigation networks.

However, the severe drought is extremely dangerous, exceeding the drought threshold, derived from the natural hazards that farmers are unable to adapt. Each year, the study area has

been affected by the different types of drought, as in 2011 and 2013, the study area affected by the second type.

Drought changes agricultural production conditions and the rice landscape in the study area. According to an interview with the Department of Agricultural Development in Quang Binh Province, rainfall levels are very low during the dry season. Since 2010, both temperatures and evaporation levels have increased.

However, precipitation levels are decreasing, thus contributing to a more severe drought. In some areas, the rice paddy landscape changes due to a change in crop type, particularly a shift from rice cultivation to maize farming because of the lesser water consumption of maize.

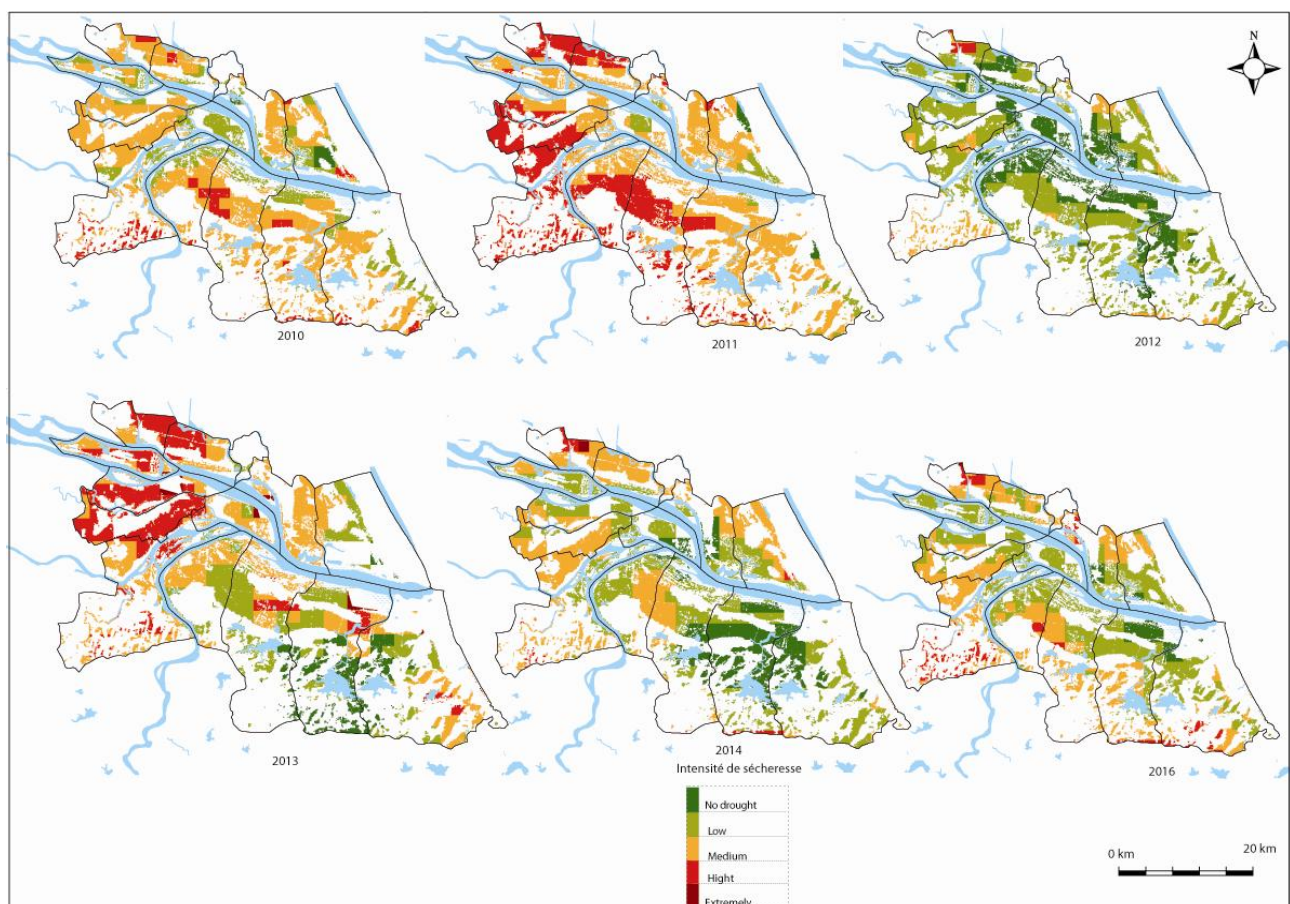


Fig. 9. Evolution of the TDVI for the agricultural zone during the agricultural period of 2010 to 2016.

On land-use planning for agricultural development, the question was worded as follows: What kind of development would you like on the Gianh River? More than 39% of respondents want to build irrigation networks, 30% want to build reservoirs to irrigate during the dry season, and nearly 20% want to plant forests; the rest want to build an industrial center to create jobs and replace crops that are struggling. From the field mission, the semi-directive and directive interviews, we can understand the situation of pressure upon water to cultivate in this region of study.

It should be noticed that rice production in the study area is facing a water shortage not only because of droughts. Other factors such as irrigation and economic/demographic growth are being poorly controlled. In this article, we propose to develop management strategies for the drought which does not yet exist in the downstream of the Gianh River. It is necessary to illustrate a map of the drought, showing the critical periods. This will provide guidance for irrigation planning policies to develop agriculture.

3.5. The impacts of changes in the rice landscape and droughts: competition for water resources

Food security in the low-lying study area depends on rice production and here water resources are critical. These resources remain at the forefront of debate through ongoing changes as a result of urban extension and demographic/industrial growth, in the context of worsening droughts (Saraswat *et al.*, 2016; Payus *et al.*, 2020; Rutten *et al.*, 2014). Therefore, our analysis of water problems is related to

climate and economic growth. "An increase in average temperatures and a higher evaporative demand combined, in some regions, with a greater rainfall risk, will weaken agricultural production" (Jamin *et al.*, 2011). Due to urban growth, the agricultural population is experiencing significant upheavals as labor migrates to other sectors in search of work. This has led to spatial and water conflicts in the study area. Also, due to the geographic location and proximity to the sea, the Provincial People's Committee wants to focus heavily on industrial activity to develop the province's economy. This policy has been implemented in all regions of Vietnam, causing widespread changes to the rice landscape.

As agricultural areas are reducing and urbanised areas are expanding, natural resources such as water are exacerbated by competition for space. Water conflicts pose problems for agricultural practices today, particularly in the dry season, where the need for water is becoming stronger and stronger.

During a field mission in 2015, we found that a rice landscape had been transformed to a maize landscape. This is only harvested one crop per year due to water shortages in the dry season. Crops grown in the dry (irrigated) season are abandoned due to water shortage, this is an important change in the study area, especially in Quang Thuan and Quang Phuc commune.

When interviewing 140 people living in the mouth of the Gianh River, among the questions asked, one dealt with the resource of cultivated: "What are the water resources to cultivate?". 105

people (75%) said that they use the water coming from the reservoir. Therefore they have to wait for rainfall to use the water. Thirty-three (23.6% of the respondents) people it's 33 people of the respondents (23.6%). And two people (1.4%) answered that they did the wells to irrigate.

Data received from the Construction Department of Quang Binh Province suggests that the level of urban water demand in 2015 has tripled since 2008. In addition, the study area has also experienced a 3-fold increase in water demand for the industry. Urbanization, industry, and tourism consume the most water. However, in the 2020 plan for residential and industrial urbanization, the construction department has not considered the water resource forecast and the need to share with other sectors such as agriculture. It seems the authorities prioritise the interests of urban and industrial growth over agricultural growth.

Rice cultivation in the study area uses groundwater that is available through storage in wells. However, the growth of population, industry and urban areas has dramatically increased water consumption, reducing the water volume available for rice cultivation. A second problem must also be mentioned: It concerns the deterioration of the quality of water due to salinization. According to an interview with the mayor of Quang Phuc commune in 2017: "... The Gianh River water resource is saline, so we cannot use it to cultivate. This town is at the end of the irrigation network and a little far from the reservoir (about 40 km). So rice growing in this commune does not have enough water to grow a second crop". Decreasing quantity of

available water and deteriorating water quality are two complementary aspects that illustrate significant changes as a result of economic activity and developments of the downstream section of the river basin.

4. Discussions

4.1. Urban layout: rapid urbanization and impacts on rice landscapes

Our paper has demonstrated that rural population growth, land policy change, the introduction of new agricultural technologies and economics have all interacted to cause significant fine-scale changes in densely populated agricultural village landscapes in the study area. Where high population density leads to demands for public infrastructure, housing, commercial uses increase. That's why construction projects start to appear (Mann, 2009). Urban growth is a new way of life, of the organization the environment. It creates a new landscape (Antrop, 2000). In the case of the study area, due to urbanization development from 1986, the agricultural landscape has been superseded, transformed. This landscape's decline certainly brings issues such as a decrease in self-supply capacity and a threat to food security in this region and water competition between non-agricultural activities and the agriculture sector, which is becoming increasingly serious in the context of climate change (Shiliang *et al.*, 2011).

In the study region, for example, of all the new urban land, about 94% was converted from agricultural land. According to the urban development projects of the construction department of Quang Binh province, 100% agricultural area in Quang Thuan town

will be removed in 2030. Thanks to the geographical situation close to the sea, the coastal corridor's urbanization is based on tourist activities. This new sector is developing and will grow stronger and stronger in the future, the coastal resource with the large coastal front, and the many benefits of heritage. The people's committee of the province of Quang Binh decided to concentrate the development of the tourism sector on several axes: the exploitation of the natural landscapes, the visit of the cultural and historical monuments, the leisure activities (swimming, leisure), and the beautiful maritime landscapes. This is an area of heritage tourism, cultural tourism-history, ecotourism, ethnic, historical and revolutionary cultural tourism, as well as maritime tourism. This accompanies the growth of construction and population. Further, places with a significant amount of agricultural lands near fast-growing urban areas or tourism area experienced the highest rates of agricultural landscape conversion (Huang *et al.*, 2009). These regions' transformations in agricultural landscapes show us that the government has a goal of economic growth thanks to industry and tourism.

The transition from the agricultural environment to the urban environment has a direct impact on health, pollution, as well as the cultivation of farmers in many areas and demonstrates that the sustainability of study area had been greatly affected (Leaf, 2002).

4.2. Climate change: a factor of change in rice-growing landscapes in the future

Drought is a natural phenomenon in extent and duration in an apparently

random manner, predominantly controlled by precipitation and temperature (Man and Modra, 2008). Both of these climate variables are projected to change along with global warming, which aggravates the drought (Yingpeng *et al.*, 2009; Duca *et al.*, 2019). The center of Vietnam could experience, in 2100, an increase in temperatures of nearly 3°C (Tran *et al.*, 2011). Pressure of natural as temperature, precipitation is increasing, albeit at different rates, to create the conditions for a future drought that is even more catastrophic than today. The rice landscape will be replaced by other landscapes, like corn landscape or abandoned.

Understanding drought's evolution, complexity to drought, will permit planners and the public to implement effective adaptation measures to reduce drought impacts. Due to climate change, the trend of increasing drought risk that began at the end of the last century will continue in the 21st century (Smit *et al.*, 2000). A developing country like Vietnam where the pace of transformation of the agricultural landscape is faster with the strong demographic growth. The improve of adaptive capacities in crop production systems, through such means as crop-production management and improvement of irrigation systems are very important to ensure food security in the study area which is one of the objects in several debates and conferences of the Government of Vietnam.

5. Conclusion

This paper analyzed the relationship between landscape change, population growth, urbanization, droughts and came to the following conclusions:

The Gianh River's mouth presents a great diversity of different landscape elements, such as; urbanisation, rice growing, fish farming, and forests. Urbanization and the development of irrigation networks have created a new rice landscape within the study area.

The dynamics of rice-growing areas seem to correlate with the economic context. The rice landscape decreases with an increase in population density. Urbanization is getting faster; therefore, large agricultural areas are being removed and replaced by commercial, residential or industrial areas.

The question of rice landscape dynamics within a fragile environment (area affected by devastating weather effects such as drought) is closely intertwined in the characteristics of this region's economic and demographic evolution.

Within the dynamics of the economy and demographic growth, the crises associated with drought are redefining the conditions of access and the sharing of water resources. This is causing difficulties in exploiting rice cultivation. This issue is becoming increasingly problematic in the context of climate change. It is envisaged that the coming years will see an intensification of dry episodes. Questions arise from this perspective: how to ensure food security in a context of demographic growth, urbanization, and industrial expansion? What are the strategies for developing agriculture in the context of droughts? The construction of irrigation networks such as reservoirs is an essential strategy to combat

droughts and increase rice yield. As sensitive and fragile areas, it is of great significance to study the impacts of economic growth and the rice landscape environment to ensure food security.

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