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Land use change and farmer behavior in reclaimed land in the middle Jiangsu coast, China



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ABSTRACT

In order to find space for urban expansion and food production, China is rapidly converting its coastal wetlands through large-scale land reclamation. These conversions are dramatically altering the coastal environment, affecting the associated ecosystem services and threatening the regional ecological security. Since this trend is expected to continue for maintaining the economic growth and food security considerations, understanding the extent of reclamation and its related land use changes is important for sustainable coastal land use planning and management. In this study, we analyze land use changes between 1977 and 2015 in middle Jiangsu coast, China, an area that is characterized by land reclamation from wetland conversion. In addition, we surveyed local farmers occupying the reclaimed land and compared their farm characteristics and attitudes against their inland counterparts to understand their role in these processes. We observed that 17% of the reclaimed land was converted to farmland and 43% to aquaculture ponds during the study period. At the same time, the natural wetlands, which originally dominated the area, were substantially reduced by 96%. Characteristics of farmers cultivating the reclaimed land were relatively similar to the inland farmer in many aspects. However, coastal farmers owned larger farms with less fragmented parcels, have a higher income from their farm and showed more enthusiasms for implementing agricultural land use changes comparing to their inland counterparts. The environmental value of the coastal wetlands and the limited opportunities for further land reclamation will pose significant challenges in the context of the region being a hotspot of urban expansion and an important contributor to food production.

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1. Introduction

Many coastal wetlands around the world are threatened or degraded due to human pressure and competition for space (Mokrech et al., 2015). Coastal land reclamation has been conducted for centuries as it provides a valuable source of new land (Wei et al., 2015). Many coastal countries, such as the Netherlands (Hoeksema, 2007), USA (Kennish, 2001), Japan (Suzuki, 2003) and Korea (Choi, 2014) have extensively exploited the sea to reclaim land for agricultural and urban development. However, coastal wetland conversion has often been accompanied with a loss of

biodiversity (Worm et al., 2006), deterioration of water quality (Day et al., 2003), disturbance of coastal currents (Wang et al., 2012), decay of organic matter (Neubauer, 2008), and other ecosystem services losses (Barbier et al., 2011; Nelson et al., 2009). As a consequence, human modification of the landscape, rather than sea-level rise, is by now the major cause of coastal wetland loss, and this is expected to continue (Kirwan and Megonigal, 2013).

China has faced more than three decades of unprecedented economic growth and its area is expanding through massive coastal reclamation activities. Hundreds of square kilometers are added onto China each year, as coastlines are extended over a length longer than China's famous "Great Wall" (Ma et al., 2014). The new structure protecting the reclaimed land is dubbed to the new "Great Wall" that increased 3.4 times over the past decades, from 18% to 61% of the total continental coastal line, reaching a length of 11,000 km in 2010 (Guan, 2013). These coastal land reclamation projects, often implemented by introducing sedimentation-

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promoting exotic plants and sand blowing, have inflicted severe damage to the coastal ecosystems (Jin et al., 2016). For example, reclamation has converted coastal wetlands from pollutant sinks to sources, producing pollutants from ports and factories; nutrients and pesticides from croplands; and chemicals, such as antibiotics, from aquacultures; resulting in deterioration of coastal environments (CCICED, 2010). Moreover, the State Council of China has approved in total 2500 km² of additional coastal wetlands to be reclaimed by 2020 (Wang et al., 2014), which could further damage the coastal ecosystems.

The loss of coastal wetlands is mainly caused by a conversion into agricultural land, driven by both economic and population growth (Van Asselen et al., 2013). Previous studies have assessed multiple aspects of coastal wetland changes, including the natural processes of coastal vegetation systems (Basnou et al., 2015), the biophysical effects in stabilizing wetlands (Larsen and Harvey, 2010), and the evolution of coastal wetland deterioration (Waycott et al., 2009). In addition, other studies have pointed at the dynamics of coastal landscapes (Bertolo et al., 2012) and its impacts on the recovery of coastal saltmarshes (Almeida et al., 2014). Correspondingly, processes and impacts of wetland conversion have been assessed in several places along China's coastline (Chen et al., 2005a; Ke et al., 2011; Tian et al., 2015). For instance, it has been observed that conversion into agricultural land or urban land is detrimental for multiple ecosystem functions, including nutrient cycling, erosion control, soil fertility, bird species and fisheries resources (Chen, 2008; Christensen et al., 2003; Chu et al., 2006; Gan et al., 2009; Li et al., 2013). However, the land use changes themselves, which underlie coastal wetland conversion of reclaimed land, have hardly been explored. Moreover, wetland goods and services are an important contributing factor to people's livelihoods (Bank, 2005). In many circumstances people depend upon the use of wetland resources in one way or another for their livelihood. (Nabahunu and Visser, 2013; Silvius et al., 2000). In this context, it is also becoming increasingly recognized that natural resource management requires a broader management approach that considers not only biophysical aspects but also farmer's decisions, socio-economic influence and policy considerations (Nabahunu and Visser, 2013). Therefore, it is of particular importance to understand the role of farmers in the process of wetland conversions and the characteristics that determine their behavior.

In this paper we investigate land reclamation activities in a typical mudflat deposition zone, the middle Jiangsu coast, China. We assess the land use and land cover changes that follow such land reclamation, and the characteristics and behavior of farmers that are the managers of land use in these areas. As the new reclaimed land provides opportunities for socio-economic development, we expect that coastal farmers in this area will show different characteristics and attitudes toward local land use changes than inland farmers. Particularly, we hypothesize that coastal farmers are younger with nucleus family (consisting of father, mother and children). Such demography would facilitate moving and this kind of generation is expected to be more entrepreneurial. We have no reason to hypothesize any difference of education level between inland and coastal farmers since the school construction and education system have no big differences across rural areas of Jiangsu province. We also expect that coastal farmers have larger and less fragmented farmland than inland farmers, since coastal wetlands are normally reclaimed and subdivided into large parcels by the local government. Consequently, we expect that coastal farmers earn more income from agriculture. Finally, we suppose that coastal farmers are willing to make more changes in the land use activities because they rely more on agricultural business and are likely more entrepreneurial. We have no reasons to hypothesize any other differences between inland and coastal farmers.

2. Material and methods

2.1. Study area

The study area is a coastal wetland on the middle Jiangsu coast, China, situated between the Yangtze River estuary and the abandoned Yellow River mouth (Fig. 1). The area is characterized by a monsoon climate with an annual mean temperature of 14.4 °C and an annual precipitation of 1088 mm (Wang et al., 2005). The wetland along the intertidal mudflat is located in a macro-tidal area, with an average tidal range of 3.9–5.5 m, and a regular semi-diurnal tide (Wang et al., 2012). The radial tidal ridge system off the Jiangsu coast, including the Yangtze River and the abandoned Yellow River delta, provides abundant sediment supply (Zhang, 1992). As a consequence, most of the Jiangsu coast is characterized by a continuous growth of intertidal mudflats, which account for roughly a quarter of the mudflats in China (Wang and Zhu, 1994). The intertidal mudflats are characterized by vegetation including Bulrush, Pantropical Weeds, Suede *Glauca* Bunge, and *Spartina Alterniflora* in the upper intertidal area, and mud flats, mixed flats, and silt-sand flats in the mid-lower intertidal areas (Chen et al., 2005b). These salt marshes are considered valuable natural wetlands, which provide important ecosystem services (Barbier et al., 2011).

The study area lies between 32°20'47" to 34°03'46" N and between 120°17'22" to 121°34'42" E along the Chinese coast. The western boundary of the study area was drawn 3 km inland from the 1977 reclamation boundary, a conceptual line that consists of artificial levees and water-control embankments. The eastern boundary was delineated to include the whole radial-shaped tidal ridge system in the southwestern Yellow Sea, and the northern and southern boundary was determined by the margin of remote sensing images used in the analysis. The study area comprises four counties in Jiangsu province, namely Sheyang, Dafeng, Dongtai and Rudong County.

Particularly, Dongtai has the largest area of coastal wetland among the counties in the study area. It has been assigned for the largest scale of coastal reclamation projects in the next five years according to the Jiangsu Coastal Region Development Planning (NDRC, 2009). Thus we chose Dongtai county as a representative for conducting the farmers' field survey since this county is expected to have more potential changes on coastal wetland conversions. Also, people related to these changes are expected to show more active characteristics and behaviors compared to their inland counterparts. Therefore, three villages on a gradient from inland to coast, Balin, Bayi and Haibin village in Dongtai county, were chosen as villages where interviews were conducted. Balin village is located at the western side of Dongtai county and closer to the county center compared to the other villages. Bayi is in the middle part of the county and famous for its cultivation of commercial crops, especially the watermelon. Haibin, the most eastern village in Dongtai county, is composed of seaward and landward parts. Fishermen live in the seaward part while cropland farmers live in the landward part. Under urbanization pressure, rural settlements in Balin village have been reorganized and concentrated according to the "New Socialist Countryside" policy and the local land use planning. The rural villages in Bayi and Haibin are located along the road or river.

2.2. Land cover classification

To assess land cover changes and related land use changes, we classified a sequence of remote sensing images (Table 1). The dates and years of these images were selected 1) to cover a time period that is as long as possible, 2) to minimize cloud cover in the images,

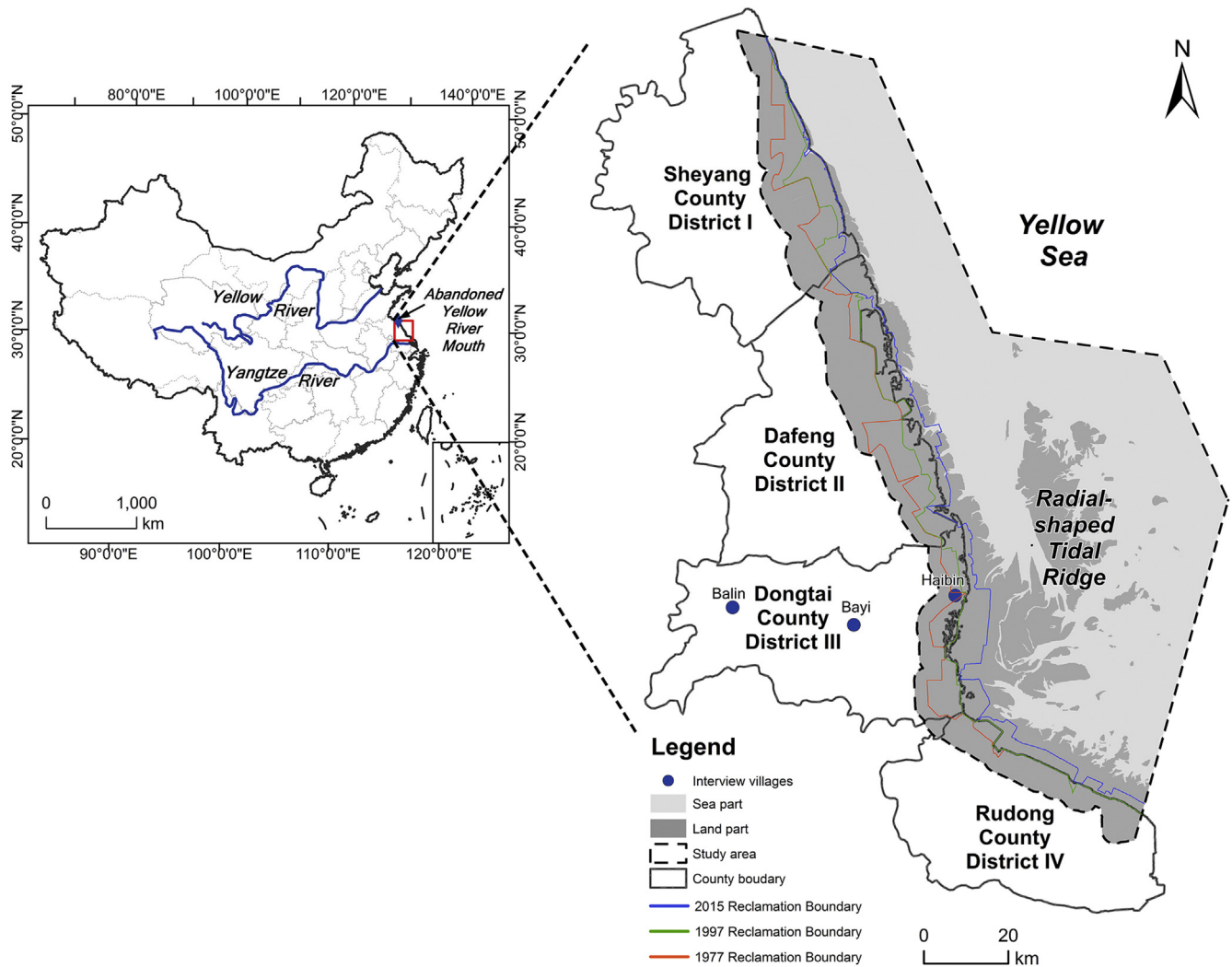


Fig. 1. Location and extent of study area interviewed villages.

Table 1
Remote sensing images used in this study.

Years	Satellite and sensor	Path/row	Date of acquisition	Resolution
1977	Landsat 2 MSS	128/37	20/04/1977	60 m
1997	Landsat 5 TM	119/37	09/09/1997	30 m
2015	HJ1B CCD1	451/75	22/04/2015	30 m

3) to cover the crop growth stage to maximize the accuracy of the vegetation classification, and 4) to expose the area of mudflats at low tide. As a consequence, we used images from different sensors (see Table 1). Layer stacking, radiometric and geometric correction, and clipping the area of interest were done for all images using ENVI 5.1 software (HARRIS, 2013). All images cover the complete study area.

Land cover was classified on screen by means of automatic classification and visual interpretation using eCognition 8.9 software (Trimble, 2013). Eleven land cover types were identified and subsequently grouped into three major groups for further analysis (Table 2). This classification was designed to match both the Ramsar Classification System for Wetland Types (Ramsar, 1971) and the Chinese Land Use Planning Classification System (MLR, 2008). The classification accuracy was assessed using 800 randomly selected sample points collected through the interpretation of Google Earth

and aerial photography of the study area. Producer and user accuracies for each class were calculated along with the overall accuracy and Kappa statistics.

2.3. Analysis of land reclamation and related land cover changes

To analyze land cover changes, we divided the study area into a steady part, a fluctuant part, and a non-reclaimed part (Fig. 2). The steady part includes the land that has been reclaimed before 1977. The fluctuant part includes the natural wetlands and intertidal mudflats that were reclaimed and converted into different land use types during the study period (1977–1997–2015). This area is defined as the land that was outside the reclamation boundary (i.e. the offshore dykes) at the start of the study period, and inside this boundary by the end of the study period. The steady part and the fluctuant part combined are both reclaimed land. The rest of study area is mostly occupied by saltmarshes, and mudflats, and is identified as the non-reclaimed part, which excludes the sea. This characterization was used to analyze the speed of the reclamation process in each district, as well as to identify the different land use changes that took place in each of the three zones.

We aggregated the land cover classes into three major groups, as indicated in Table 2. These groups, natural wetlands, human-made wetlands, and non-wetland areas, were subsequently used to

Table 2
Land cover types and detailed description.

Major land cover group	Land cover type	Detailed description
Natural wetlands	Mudflat	Intertidal mud, sand and salt flats; situated outside of the reclamation boundaries
	Saltmarsh	Bulrush, Pantropical Weeds, Suede <i>Glauca Bunge</i> , and <i>Spartina Alterniflora</i> ; situated both inside and outside of the reclamation boundaries
	Tidal creek	Channels or streams where water flows in both directions, due to tides; situated outside of the reclamation boundaries
Human-made wetlands	Irrigated farmland	Irrigated agricultural areas, mainly paddy rice; situated inside of the reclamation boundaries
	Aquaculture pond	Fish, crustaceans, mollusks, algae, and sea vegetable farming in freshwater environments; situated inside of the reclamation boundaries
	Irrigation canal and water storage area	Channels for transporting water for farming or landscaping, situated along or inside of the reclamation boundaries; Reservoirs, barrages or dams; situated inside of the reclamation boundaries
Non-wetland areas	Dry farmland	Cropland areas without irrigation; situated inside of the reclamation boundaries
	Road	National, provincial, prefectural, and country roads; situated along or inside of the reclamation boundaries
	Construction land	Urban and rural settlements, factories and infrastructure; situated inside of the reclamation boundaries
	Forest	Natural and planted forests; situated along or inside of the reclamation boundaries
	Saline land	Bare lands with high soil salinity, free of vegetation; situated inside of the reclamation boundaries

analyze wetland conversion in the steady, fluctuant and non-reclaimed part of the study area and for each county. Specifically, we identified wetland loss (changes from natural or human-made wetlands into non-wetlands), wetland gain (changes from non-wetlands into natural or human-made wetlands), wetland transition (changes between natural and human-made wetlands) and internal evolution (changes between land covers in one major group). The detailed land cover maps before aggregation were then used to find what conversions exactly underlie these changes.

2.4. Farmer interviews

We used a household survey to investigate farmers' properties and attitudes that could influence their land use decisions (Fig. 2). The survey was conducted based on 54 randomly selected interviewees in Balin, Bayi and Haibin village. The number of the interviewees was equally distributed for the three villages and no focus group was involved during the survey. The sample consists of

a very small fraction of the manifold larger population of the villages but is, given the random sampling design and relative homogeneity of farm characteristics in the villages considered to be representative. The questionnaire consisted of three groups of questions. The first group related to farmers' properties, like their family size, age of family head, and education level. The second group contained questions about farmers' incomes from different agricultural activities like cropping, livestock, and aquaculture. The last group assessed the attitudes and motivation towards making certain land use decisions. Answers to these questions were coded into continues or discrete variables and used to assess whether there is difference between farmers in the reclaimed areas and farmers cultivating old land. The Mann-Whitney test was used to analyze whether family size, age of family head, educational level, total area of farmland, farmland fragmentation and income from agriculture were different between inland and coastal farmers, as these independent variables are measured using ordinal or ratio scales. A Chi-square statistic was used to assess the distribution of

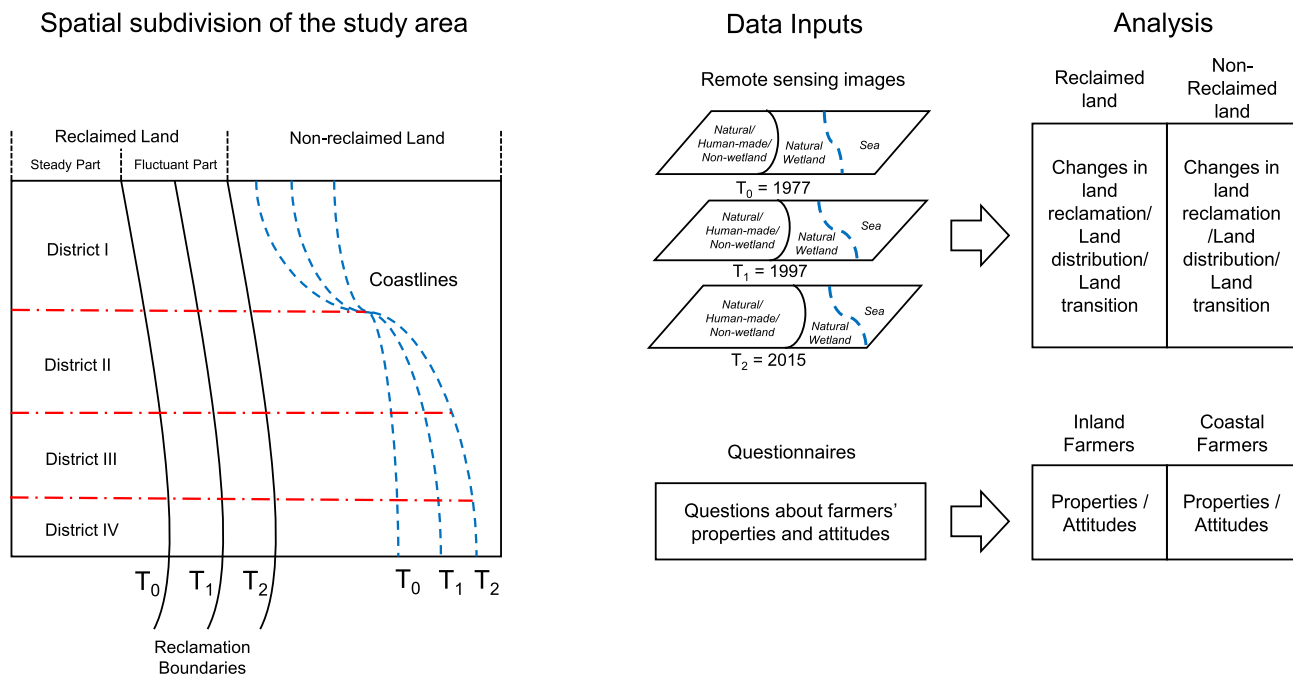


Fig. 2. Overview of research methodology and subdivision of the study area.

categorical values for farmers' attitudes toward agricultural land use and settlement changes.

3. Results

3.1. Land cover classification

The result of the land cover classification is shown in Fig. 3. The overall accuracy of the land cover classification for the years 1977, 1997 and 2015 is 93.9%, 95.7% and 88.2%, respectively (see Table 3). This is considered acceptable for this study, following (Anderson et al., 1976). The corresponding Kappa value, the user's accuracy and producer's accuracy for the individual land cover class are provided in Table 3. These values indicate that the maps are sufficiently accurate for further analysis. Moreover, the inaccuracies are distributed across the area and land cover types while the change in land cover observed in much more spatially concentrated and focused on specific conversions, standing out from possible random fluctuations in land cover and inaccuracies in the classification.

3.2. Land reclamation along the middle Jiangsu coast

The total land area of the study region has increased only slightly over the past 40 years, from 4387 km² in 1977, to 4436 km² in 1997, and 4454 km² in 2015. At the same time, the shape of the land area has altered much, due to erosion and deposition processes as well as human activities (e.g. land reclamation). Consequently, the total area has decreased in the northern two districts, while it has increased in southern two districts (Fig. 4).

Land reclamation activities have been undertaken in all districts. Therefore, the area of reclaimed land, including both the steady part and the fluctuant part, has increased in all four districts, from a total area of 1346 km² in 1977–2710 km² in 2015. Consistently, the

non-reclaimed land has decreased from a total area of 3041 km² in 1977 to 1743 km² in 2015. Due to the uneven distribution of land reclamation activities, in combination with the erosion and deposition processes along the coast, only a small part of the land in Sheyang and Dafeng was not reclaimed by 2015 (5.8% and 16.5% respectively). On the other hand, there is still a large amount of non-reclaimed land in Dongtai (68.1%, see also Fig. 4).

3.3. Land cover changes along the middle Jiangsu coast

The distribution of the three major land cover groups (natural wetlands, human-made wetlands, and non-wetland areas) in the steady and the fluctuant parts varied over time (Fig. 5). At the beginning of the study period, non-wetland land covers were dominant in the steady part, followed by natural wetlands and human-made wetlands. Between 1977 and 1997, both non-wetland land covers and natural wetlands decreased by around 17%, while human-made wetland increased by nearly 34%. In the last two decades, non-wetland land covers and natural wetlands further declined, while human-made wetlands increased by the same amount. As a consequence, natural wetlands were substantially reduced by 96% in the whole study area, while human-made wetlands (particularly irrigated farmland) were the dominant land cover in Sheyang, Dafeng and Rudong County. Only Dongtai County was still predominantly characterized by non-wetland land covers (especially dry farmland).

Between 1977 and 1997, land cover changed in 70.8% of the steady part. Among these changes, 30% of the changes were due to wetland gains, followed by internal evolution, wetland loss and wetland transitions (Fig. 6). Considering all the land cover changes in this part, the most drastic land cover changes were the expansion of irrigated and dry farmland. Changes to aquaculture ponds also contributed 14% changes during this time. However, between 1997

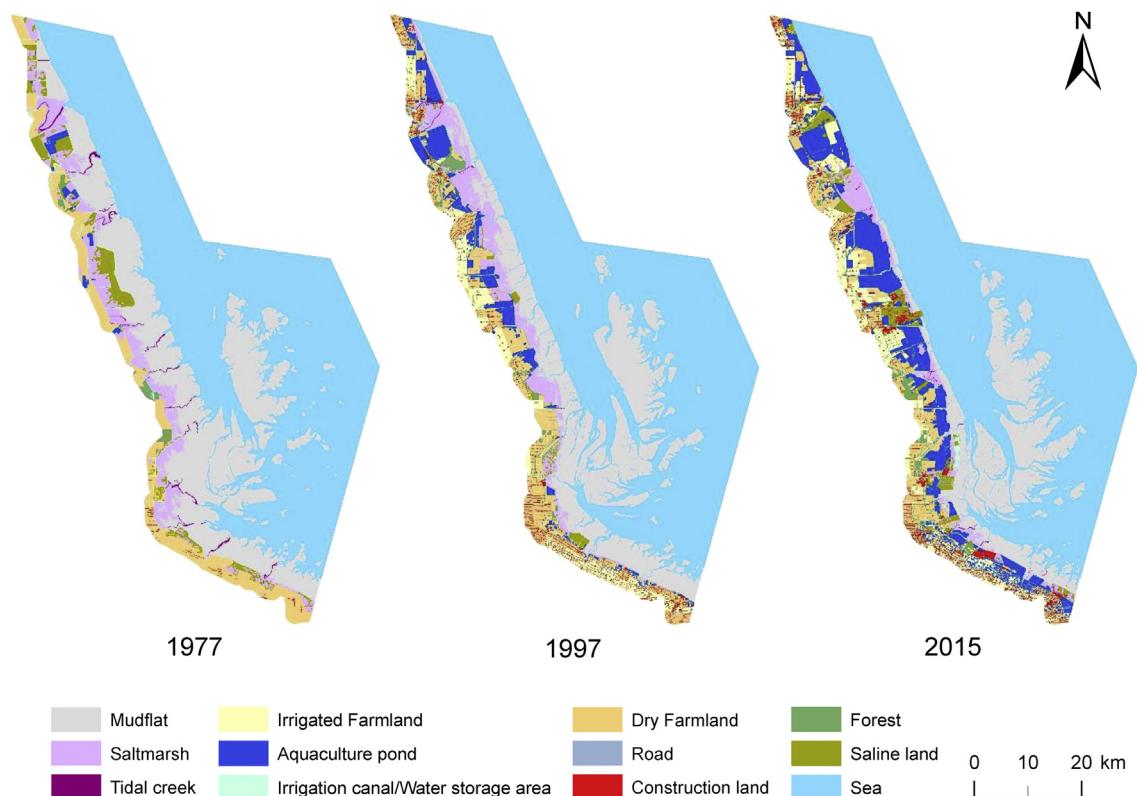


Fig. 3. Land cover maps of the study area in the year 1977, 1997 and 2015.

Table 3
Accuracy assessment results.

Land cover class	1977		1997		2015	
	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy
Mudflat	98	100	89	100	94	87
Saltmarsh	99	83	100	95	93	87
Tidal creek	96	100	98	90	64	92
Irrigated farmland	—	—	98	100	91	91
Aquaculture pond	100	100	97	100	88	80
Irrigation canal/Water storage area	100	97	98	97	84	92
Dry farmland	86	94	89	100	84	89
Road	96	93	98	91	96	94
Construction land	91	79	99	96	89	80
Forest	83	95	95	61	77	84
Saline land	92	96	83	85	90	88
Overall accuracy	93.9%		95.7%		88.2%	
Kappa Statistics	0.93		0.95		0.86	

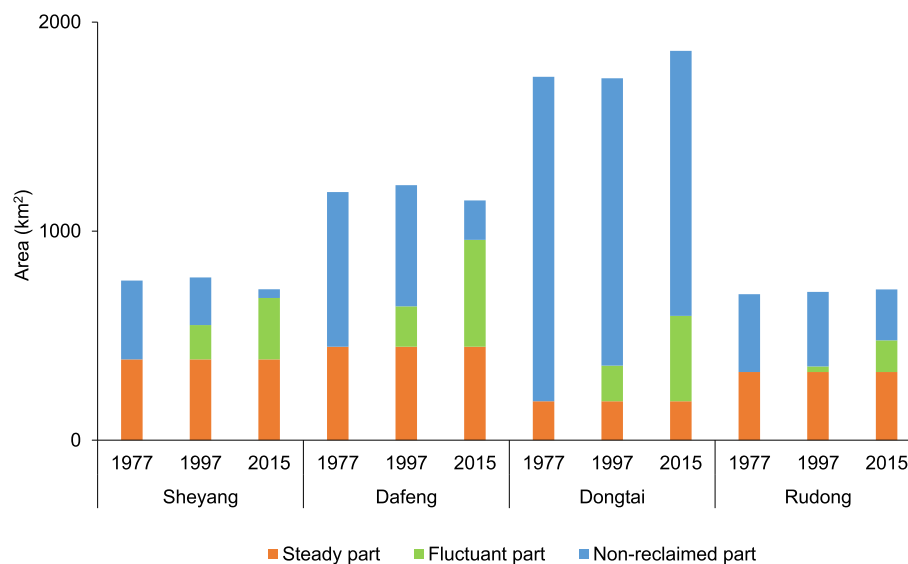


Fig. 4. Changes of reclaimed (steady and fluctuant) and non-reclaimed land in the case study area. The steady part, by definition, remains constant over time and is shown only for reference.

and 2015, the landscape in the steady part showed a lower degree of changes due to the persistence of large areas with anthropogenic cover types. In spite of such stability, a consistent wetland gain, internal evolution and wetland loss were observed, while wetland transitions only occupied 2% of the whole changes. These major wetland conversions were lead to the on-going expansion of agricultural areas, involving 10% of changes to irrigated farmland and 8% to aquaculture ponds and dry farmland.

In the fluctuant part, the land cover distribution shows a different situation in the two study periods. At the beginning of the study period, all land in the fluctuant part was covered by natural wetlands, as this was not yet reclaimed. Between 1977 and 1997, more than half of the natural wetlands were reclaimed into non-wetland land covers. Meanwhile, one third of the newly reclaimed land was converted into human-made wetlands, while the left part remained stable as natural wetland. In contrast, between 1997 and 2015, the majority of the natural wetlands were reclaimed into human-made wetlands. Conversions to non-wetland land covers accounted for one third of all the changes, while there still existed 9% of the natural wetlands at the same time. As a consequence, human-made wetlands became the major land cover types in all districts over the past two decades.

Specifically, between 1977 and 1997, changes in fluctuant part

are mainly due to wetland loss and transition (Fig. 6). Around one third of the natural wetlands were replaced by dry farmland, and another 26% of them were transformed into aquaculture ponds. Meanwhile, the natural wetland was also partially affected by the plantation of shelter forests after reclamation. However, a tremendous change of wetland transitions from natural to human-made wetland was observed between 1997 and 2015. The natural landscape was significantly replaced by the dominant gain of new aquaculture ponds, covering half of the land cover changes in the fluctuant part. The remaining half of the landscape were mainly converted into saline land and saltmarshes, which resulted in one third changes of wetland loss and 7% of the internal evolutions.

Simultaneously, the non-reclaimed part, which is covered by the natural wetlands, consistently reduced in all districts due to the large-scale reclamation activities.

3.4. Farmers' properties and attitudes

Interview results show that farms in coastal areas are on average much larger and less fragmented than in the inland areas. These differences originate from the way in which land was highly planned by the local government and provided to coastal farmers, aiming for economically and agriculturally productive units.

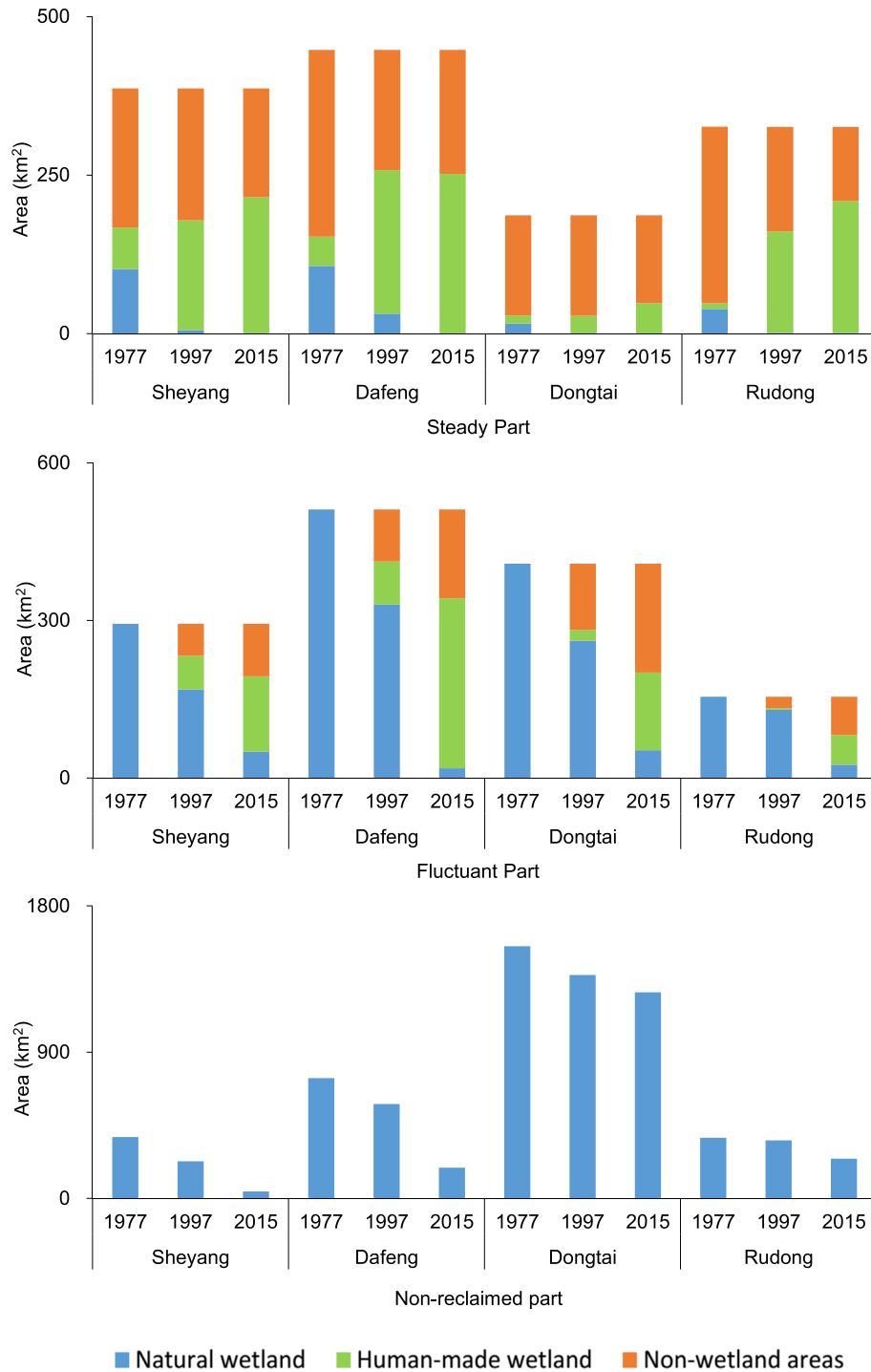


Fig. 5. Major land cover distribution in the steady part, the fluctuant part and the non-reclaimed part in the year 1977, 1997 and 2015.

However, land allocation in inland areas follows the traditional way by regulating farmland resources in response to changes in the size of farmer's families and labor migration. As a consequence, most coastal farmers are full-time commercial farmers, while most inland farming is still subsistence farming. Therefore, logically, the income of coastal farmers from farming activities is significantly higher than the income inland farmers receive. All these differences are statistically significant and thus confirm our hypotheses about the difference between coastal farmers and inland farmers (see Table 4). Interview results reveal only small differences in the

family size, age of family head, and educational level of inland and coastal farmers (see Table 4). As none of these differences were significant, this confirms our hypothesis about the education level. At the same time, these results reject our hypotheses that coastal farmers differed from their inland counterparts in terms of their family characteristics. While we expected that coastal farmers have smaller families, i.e. less than two generations in one family, because this would facilitate moving, this was not observed in reality.

Chi-square tests indicate that coastal farmers are willing to

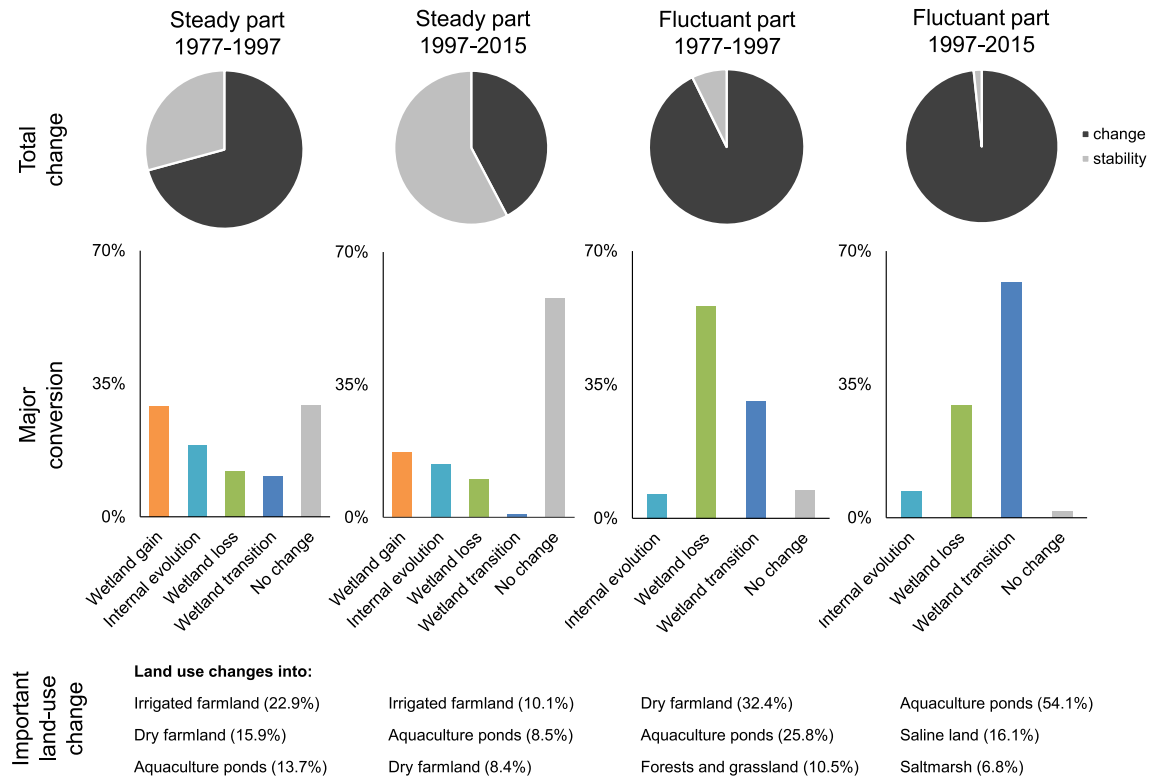


Fig. 6. Characterization of land cover transitions in the steady part and the fluctuant part of the study area in the periods 1977–1997 and 1997–2015.

Table 4

Differences between inland and coastal farmers' properties, conditions and attitudes toward local land use.

Variables	Inland mean value	Coastal mean value	Test	Significance	Null hypothesis	Evaluation
Family size	4	4	Mann-Whitney	0.400	Inland family size is bigger than coastal ones because coastal families are new immigrants from inland villages to coastal areas.	Rejected
Age of family head	55	55	Mann-Whitney	0.526	Inland family head is older than coastal one because coastal families are new immigrants from inland villages to coastal areas	Rejected
Educational level	Middle school	Middle school	Mann-Whitney	0.719	There is no difference between inland and coastal farmers	Confirmed
Total area of farmland	0.3 ha	4.8 ha	Mann-Whitney	0.001**	Coastal farmers have larger area of farmland than inland ones because coastal wetlands are reclaimed into large scale	Confirmed
Farmland fragmentation (number of plots)	5	3	Mann-Whitney	0.000***	Coastal farmers have lower degree of farmland fragmentation than the inland ones because coastal wetlands are reclaimed into large piece	Confirmed
Income from agriculture	3013 USD	12,686 USD	Mann-Whitney	0.001**	Coastal farmers have more income from agriculture than inland ones because coastal farmers own larger farms than inland ones.	Confirmed
Whether to make changes on agricultural land use (e.g. expand current farmland or adjusting the planting structure)	2 persons out of 36	7 persons out of 18	Chi Square	0.017*	Coastal farmers want to make more changes on agricultural land use than inland ones because coastal farmers rely more on agricultural business than inland ones.	Confirmed
Whether to make changes on current settlement location (e.g. abandon it to move to big city)	4 persons out of 36	3 persons out of 18	Chi Square	0.567	Inland farmers want to make more changes on current settlement than coastal farmers because inland farmers live more close to the city center than coastal farmers	Rejected

*P < 0.05, **P < 0.01, ***P < 0.001.

make more changes on agricultural land use than inland farmers, for example by expanding their farmland, adjusting the planting

structure or shifting the farmland into aquaculture ponds. During our survey, coastal farmers cultivate the farmland not only for

subsistence, but also to sell large amounts of produce to the market. In contrast, inland farmers typically own small and fragmented farmland, which is used for subsistence only, or to rent out to others, or partially selling the outputs to local agricultural market. Since the income from agriculture is much lower than that from off-farm jobs, most inland farmers have limited expectations of their agricultural business, and wish to seek well-paid off-farm jobs in nearby cities. This attitude can potentially explain why agricultural land use was more stable than the reclaimed land. We also assessed farmers' willingness towards changing the location of their household. The Chi-square test indicates that there is no significant difference between inland and coastal farmers concerning their attitude towards abandoning their houses to move to a big city.

4. Discussion

4.1. Impacts from coastal land reclamation and land use changes

This study shows no signs of a decrease in land reclamation activities along the Jiangsu coast. Instead, our observations are consistent with the provincial statistics, which show that about 2747 km² of coastal wetland has been reclaimed in Jiangsu province between 1951 and 2008 (Zhang et al., 2013). As the government plans to reclaim another 1805 km² of mudflats until the year 2020 (NDRC, 2009), this wetland system is expected to face further disturbance. However, at the same time the growth rate of non-reclaimed land (e.g. mudflats) was much lower, suffering from sediment restrictions associated with dam construction in upper catchments (Yang et al., 2005). Along the middle Jiangsu coast, Sheyang and Dafeng County have almost no land left to reclaim, while Dongtai and Rudong County still have a relatively large amount of natural wetlands left. Despite that, all districts continue their ambitions to reclaim land, caused by both the national coastal strategies and local economic needs. According to our analysis, the limited non-reclaimed land available might constrain such ambitions. These limitations can also be found in other coastal parts of China, like the Yellow Sea region (Murray et al., 2014) and the Pearl River Delta (Chen et al., 2005a) where economic development intensifies the land reclamations while the degradation and loss of coastal wetlands challenge these activities owing to the unbalanced competition for using natural resources.

Meanwhile, land use dynamics are important in determining the stability of coastal wetlands as they shape the coastal landscape. During the first two decades (1977–1997), the expansion of dry or irrigated farmland in both the steady and fluctuant part strongly changed the coastal landscape. The observed changes reflect the agricultural transformation occurring in China where efforts to increase productivity were stimulated by a shortage of food supply. Land use changes showed a different trajectory in the last two decades (1997–2015). In our study, new aquaculture ponds were developed in both the fluctuant and steady part, and such changes reflect the search for opportunities to make economic profits. As a result, great loss of natural wetland was observed during this period. Our analysis indicates that these wetland conversions are accelerating at a rate comparable to other coastal landscape changes in some regions of Asia where 12% of the area of mangrove forests has been converted to agriculture and aquaculture (Giri et al., 2008), despite evidence that these systems provide protection against tsunamis and storm surge (Barbier et al., 2013; Das and Vincent, 2009).

4.2. Farmer decision making

Land managers and their decisions play an important role in the changes on the reclaimed land. We expected that the farmers on

the new land, which include both cropland farmers and fish farmers, would be different from the inland farmers. However, our analysis indicated that, for household characteristics, there is no big difference between inland and coastal farmers. The family size is almost the same with an average level of 4 persons (Table 4) in both inland and coastal villages. We, incorrectly, hypothesized that the new land would provide opportunities that would especially attract young and entrepreneurial families. The family heads in the studied villages had an average age of 55 years with a middle school diploma (Table 4). This kind of age and educational level used to be considered as the “experienced and literate generation” which is actively involved in agriculture, with a longer planning horizon and more adopters (Bidogeza et al., 2009). However, results from the interviews indicate that the characteristics of “this generation” are not the main determinants for local land use changes in Jiangsu coast. Instead, the characteristics of the farms themselves can explain some of the differences in land developments.

As a consequence of the planning processes farms on the coastal reclaimed land are generally large and hardly fragmented, providing opportunities for full-time commercial agriculture. Fishery farmers in the seaward part of Haibin village own large pieces of aquaculture ponds and have considerable income from these farm practices. They have established a new rural cooperative that provides them with enough funds to get involved into more agricultural business. Simultaneously, farmers in the landward part of Haibin village are motivated to rent more farmlands or adjust their planting structure since they own large pieces and less fragmented farmland resources. Inland farming, on the other hand, is mostly subsistence farming while family members have off-farm jobs to complement their income. In addition, the conversion of much agricultural land into urban fabric, especially near Balin village, has led to a reduction of cropland, and reduced opportunities for cropland farmers. Consequently, few Balin farmers have ambitions to make changes on their small and fragmented agricultural land. While farmland conditions are better in Bayi village, more than 90 percent of the farmers that are interviewed have no interests in expanding their farmland or adjusting their agricultural practices to increase production, due to the uncertainty of agricultural markets and the lack of successors in their family. Hence Balin and Bayi show similar land use characteristics, even though the underlying causes for the lack of changes and the motivation for farms to make investments is different.

Similar findings are found in other studies in wetland agriculture area where farmer wealth is fundamentally determined by farm size and land resource availabilities (Nabahunu and Visser, 2011). Consequently, at the household level, large reclaimed farms can bring benefits for local farmers to acquire more agricultural resources and incomes, and further stimulate the local labor market for additional enterprises in the agricultural system.

4.3. Implications for future land reclamation

What we observed about land use changes and farmers' behavior in middle Jiangsu coast is an epitome of China's coastal reclamation development. In particular, the combination of the arable “red-line” and the ongoing urban expansion is an important driver of the coastal reclamation activities. While there are many similarities with other parts of the Chinese coastline the studied changes are especially representative for the Jiangsu province coast. China is at the point of breaching its so-called “red-line” — the 120 million hectares of arable land that must be left available for agriculture. Since any agricultural land taken over for urban development has to be compensated by an equivalent area of newly created agricultural land elsewhere, reclaiming wetlands and stimulating reclamation processes to accommodate land

development while leaving existing farmland intact remains an important strategy. Thus large-scale coastal land reclamation projects are likely to continue.

China's administration has recognized the value of marine ecosystem-services, and realized the negative impacts of large-scale land reclamation on marine ecosystems (Wang et al., 2014). However, a contradiction between central government's control and local bureau's ambitions has potentially influenced the coastal reclamation process. Since the 1980s, China has made great efforts in the formulation of policies and plans governing coastal development and utilization (Wang et al., 2014). For example, according to "Jiangsu Coastal Region Development Planning (2006–2020)", newly reclaimed land distribution should be distributed following a strict ratio between agricultural, built-up, and natural land (6:2:2) (NDRC, 2009). However, in order to support more development projects and avoid large-scale reclaimed space (>50 ha) approved by the central government, local bureaus divide the large projects into smaller ones and avoid reporting them to the central government to gain accumulative built-up amounts. Therefore, the real reclaimed ratio turns to be 2:6:2 or even 2:7:1 in practice according to our analysis. The central government is now confronting the challenges from local actions and has no better solution to avoid this phenomenon because they also want to maintain a certain degree of economic growth especially in the coastal part.

These developments are disturbing China's coastal development plans and forcing the government to rethink its new "Great Sea Wall". This "Great Sea Wall" is not only formed by thousands of kilometers of seawalls, but also carries the desires of the country for more potential food supply and living space. Globally, economic incentives to expand arable land, harvest resources and protect infrastructure investments have long motivated humans to actively alter the land-sea margin. Such activities have generally served to degrade the coastal wetlands and are going to be intensified with ongoing global population growth and economic development. However, it is to be determined at what environmental costs such projects are acceptable. To the question, it is needed to integrate studies of wetland processes with research on biophysical and social-economic factors that underpin the dynamics of coastal wetland functions prior to their large scale reclamation and assess the risks of reclamation on coastal protection. Alternative strategies to improve the efficiency of interior land use could be combined with more ecosystem-based measures of coastal development could provide opportunities for a more sustainable land-sea interaction in the future without further expanding the "Great Sea Wall" (Ma et al., 2014).

5. Conclusion

Our work assesses land use changes in the middle Jiangsu coast before and after coastal reclamation activities and confirms the rapid increase of human land use at the cost of coastal natural landscapes. Squeezed between the shoreline and the expanding human pressure from the land, Jiangsu coastal landscapes have, over the course of the last 40 years, been disturbed and transformed by several threats, such as agriculture and urbanization. Particularly, the expansion of dry or irrigated farmland was observed from 1977 to 1997 while in the recent two decades an increasing conversion to aquaculture ponds was identified. Moreover, in order to understand the traditional land use patterns and newly reclaimed land use, inland and coastal farmers' properties and their attitudes have been surveyed and tested. We found no significant difference between properties such as family size, age of family head, and educational level. However, differences were found in farm size and fragmentation of plots as well as in farmer's attitudes toward local land use changes. Coastal farmers who own

large and hardly fragmented farmland are more active to get involved into agricultural land conversions, while the inland farmers with small and scattered farms are less interested in local land development. The size and pattern of the farms, instead of the characteristics of farmers, are the main determinants for the explanation of farmers' attitudes toward agricultural land use changes in middle Jiangsu coast.

This research shows the large extent of land conversion in this region, which essentially comes at a cost of valuable coastal ecosystems. Accounting for the trade-offs between the protection of natural wetlands and their functions and the benefits of further expanding the area of reclaimed land would avoid an irreducible reduction of these natural wetlands. These trade-offs relate to direct consequences as a result of wetland conversion, as well as indirect consequences, as a result of developments near the coast, as these developments, including ports, factories and aquaculture farms are often sources of pollution and eutrophication, which further harm the remaining natural wetlands. Moreover, protecting coastal wetlands will also benefit the reclaimed land as these wetlands provide a natural protection against coastal flooding and storms and mitigate shoreline erosion to shield people and the habitats.

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