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Research Article

The Influence of Land Consolidation on Biomass and Ecological Environment

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Abstract: Land consolidation changes the land use types and then the biomass. The measure and calculation of biomass fore-and-aft land consolidation worked out by the sample plot method in terms of arbor, shrub, herbage plants and crop. The result shows that the biomass is increased 580 t after land consolidation, meaning the impression of land consolidation is remarkable in general. The results of monomial analysis are as follows: (1) the biomass of sparse forest is no changed fore-and aft land consolidation, but its ratio of biomass is reduced down 2.5% and its ecological influence is slightly weakened; (2) the biomass sum of manpower forest and sparse forest is increased up 6% after land consolidation, so that the total ecological influence of woodland is enhanced; (3) the waste grassplot is disappear of land consolidation, so that its ecological influence; (4) the total biomass of dry-land crop is all most no change, but its influence is reduced down 17.87%; (5) the total biomass of rice is increased up 477.94 t after land consolidation, account of 82.4% of increased amount and its total ecological influence is up to 14.12%. The results also show: (1) the structure and function of regional ecosystem will be changed by land consolidation and the biomass will be changed accordingly; (2) marked ecological influence will be induced from the biomass change, not only the natural ecosystem, but also the human ecosystem.

Keywords: Biomass, biomass balance, ecological influence, land consolidation

INTRODUCTION

Land Consolidation (LC) is an approach for sustainable rural development (Pasakarnis and Maliene, 2010; Huang *et al*., 2011). Land consolidation is the most favorable land management approach for solving land fragmentation and has been applied in many countries around the world (Demetriou *et al*., 2012) and has in general made a positive contribution to slowing rural depopulation (Miranda *et al*., 2006). In China, LC is worked out to adjust the manner of regional land use, constituted of four engineering systems such as land leveling engineering, farmland irrigation works engineering, road construction engineering and protection forest engineering (Yu *et al*., 2010). Land consolidation changes the types and spatial pattern of regional ecosystems to form an artificial succession of ecosystem. Following the succession, the structure and functions of ecosystem is changed, the biomass of regional biocenosis is also changed and a man-made ecosystem succession is taken place. The biomass change determines influence capability of regional biocenosis to regional environment.

The biomass change, resulted from integrated effect of environmental factors, is one of the symbols of community succession and of regional exhibition of global change. The succession of natural ecosystem reflects the regional response mechanism of global change and the succession of artificial ecosystem reflects the contribution of human activities to global change. The drive-forcing of biomass change is different between the natural and artificial ecosystems and regional biomass is related to the type of biotic population, the obvious difference is taken place in different regions and different biotic populations. The regional biomass change is restricted by many factors such as intra-annual rainfall variability (Nippert *et al*., 2006), dietary shift (Plisterer *et al*., 2003), land use and land cover change (Hietel *et al*., 2004; Taverna *et al*., 2004; Brandt and Townsend, 2006), disturbed effects (Aggarwal *et al*., 2006; Wimberly, 2006; Mou *et al*., 2005) and so on. Many attentions are focused on the impacts of land use change to biomass (Taverna *et al*., 2004; Benjamin *et al*., 2005). Spatial patterns of biomass and biotic transitions at multiple scales are discussed (Sherman *et al*., 2003; Peters *et al*., 2006) and many models of biomass estimation are developed in terms of the 3-PG model (White *et al*., 2000), the forest inventory data (Zhou *et al*., 2002) and other statistic data (He *et al*., 1998; Tang *et al*., 2000). Considering the roles of environment variables and endogenesis variables in biomass change (Cheng *et al*., 2000), a lot

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of models are developed to describe the biomass changes in different region and different types of vegetation such as in the forest ecosystems (Zhou *et al*., 1995; Fang *et al*., 1996; Liu *et al*., 1994), the wetland vegetation systems (Wang *et al*., 2004), the artificial forest systems (Hiratsuka *et al*., 2005), the scrub ecosystems (He and Wang, 1997), the grassland systems (Nippert *et al*., 2006; Zhu *et al*., 2002; Li *et al*., 2000), the hungriness ecosystems (Zhao *et al*., 2004) and cropping systems (Ren *et al*., 1997; Dong *et al*., 1999; Chen *et al*., 2004; Zheng *et al*., 1994) and so on. Remote sensing and geographical information system are introduced to quantify observation and data processing for biomass (Zhang and Fu, 1999; Ollingger *et al*., 1998; Scheller and Mladenoff, 2004).

There are many mature techniques to determine the biomass in the scale of community for plant community, animal community (Xu *et al*., 2004; Zeng *et al*., 1994; Ye *et al*., 2004) and microbial community (Shao and Zhao, 2004; Staley, 1999). Especially, there is a mass of reports to the researches on the biomass of plant community such as crop (Dong *et al*., 1999; Tao and Zhong, 2003; Chen *et al*., 2004), forest (Zhang and Fu, 1999; Fang *et al*., 1996; Liu *et al*., 1994; Wu and Feng, 1995), shrub forest (He and Wang, 1997; Guan, 1998) and prata (Wang *et al*., 1995), the other researches are worked out on the biomass of overground parts and underground parts of plant (Li and Lin, 1998; Zhao *et al*., 2004) and the else on the biomass of plant apparatus (components) (Yin and Liu, 1997). A good deal of special study is done on the biomass change under the influence of different ecological factors (Yan *et al*., 2004; Xiao *et al*., 2004) and the change under human intervention such as cultivation, graze, fertilization and engineering construct and so on (Zhu *et al*., 2002; Li *et al*., 2000). The research technique and approaches are discussed from different angles as follows: the 3D model (as UN model and Lattice model) based on Arc/Info is used to estimate the total biomass for forest community and compared the results to the 2D model (Liu *et al*., 2004); the full weight method is used to determine the organic biomass of plant swatch and then the mathematical model is built in term of independent variable of stem girth for integrated measure and calculation (Zhou *et al*., 1995); the biomass is rapidly measured by the fresh weight of its some apparatus (Wang, 1997); and the optical remote sensing and radar remote sensing are used to determine the plant biomass in wetland (Wang *et al*., 2004).

All above the achievements are supplied us with the basic theories and methodologies of demonstration to study the biomass change in land consolidation, but there is no direct report to research on the biomass change caused from the land consolidation.

As well as the environmental impacts of land use changes (Veldkamp and Verburg, 2004; Lindeijer, 2000), many economic, social and environmental impact resulted from land consolidation (Crecente *et al*., 2002; Yu *et al*., 2006a, b; Yu *et al*., 2007; Yu *et al*., 2010). In this study, to explore the influence degree of land consolidation to regional ecological environment with the case study of a state invention project of land consolidation in China, the biomass change fore-and-aft land consolidation is analyzed in views of the influence from the land consolidation on regional biomass, the environmental effects of biomass are discussed and so the ecological effects of land consolidation.

MATERIALS AND METHODS

Experiment area: The experiment area is situated on the northeast of Hong *et al*. (1999) Hong'An County, Hubei Province, located on 114°31′ E~114°39′ E and 31°23′ N ~31°24′ N. It is the foothill on the southwest of the Da-Bie Mountains. Its topography is downward from the North to the South in the region, with the hill and hummock in the north and flat paddy fields in the south. The altitude is between 73.9 to 117.8 m in the region. The elements of physiognomy are constituted of hill, hummock and flat paddy field by river. The hypsography in the middle part is relative flatness and the soil is fertility. The climate is the monsoon climate of North subtropical zone, with the flush rainfall, the plenitude illumination, the geniality weather, the clearly four seasons and the long non-frost period. The annual mean sunlight time is 1998.9 h, the mean sun radiation is 107.79 kcal/cm^2•a, the annual mean temperature is 16.2°C, the tiptop of monthly mean temperature is 28.2°C, the minimum of monthly mean temperature is 2.4°C, the extremity of temperature is -14.5°C and the active accumulated temperature is upwards 4000°C. The non-frost period is between 235 to 241 day and the annual rainfall between 1021 to 1154 mm. The mean period of rainfall is 110 day/a, the rainfall is mostly centralized from the March to the July, account for 52% of annual rainfall period. The surface runoff is 550 mm in hill and 450 mm in flat paddy field.

In the experiment area, the vegetation is mainly natural shrub and man-made forest, with the sparse Masson pine and the low frutex. There are many sparse aspen around the residential area. The shade density of vegetation is low in the experiment area. The economic crop is mainly Chinese chestnut, peach and pear and the crop is consisted of paddy, wheat, peanut, potato, watermelon, cotton and so on (Table 1). The structure of land use is adjusted in the land consolidation for the experiment area (Table 2).

The total area of experimental field is 237.7 hm^2. The primary type of land use is farmland and other types are woodland, roadway, depose factories and mines, wasteland and so on. The structures of land use in fore-and-aft land consolidation are shown in Table 2.

The biomass observation:

The arbor layer observation: Investigating the sample wood in the standard sample area, measuring the mean bosom diameter, the mean tree highness, the density

Table 1: The constitute of key phytocoenosium in experiment field

	Type of vegetation	Type of biocenose	Constructive species	Dominant species
Woodland	Evergreen broadleaved forest	Arbor community	Masson pine	Masson pine
	Deciduous broadleaved forest	Arbor community	Italy aspen	Italy aspen
	Non-timber production forest	Arbor community	Apple, orange and pear	Orange
	Subtropical shrub	Shrub community		
Cropland	Dry-land crop	Herbaceous community	Wheat	Wheat
	Dry-land crop	Liane community	Potato, peanut, watermelon	Potato
	Wetland crop	Herbaceous community	Rice	Rice
	Wetland crop		Cole	Cole
Garden plot			Chinese cabbage	Chinese cabbage
Water area	Water plant		Hyacinth, aquatic, algae	Hyacinth
Wasteland		Herbaceous community		

Table 2: The change of land use structure in experiment field

Plots	ck	Total (ha)	Farmland (ha)	Woodland (ha)	Roadway (ha)	Depose factories and mines (ha)	Wasteland (ha)
Kuangshan	Before LD	125.20	101.360	3.14	0.400	19.7	0.600
	After LD	125.20	118.620	4.21	2.370	0	0
	Change	0	17.260	1.07	1.970	-19.7	-0.600
Wantianfan	Before LD	112.50	98.845	0	0.696	0	12.959
	After LD	112.50	110.230	1.34	0.930	0	0
	Change	0	11.385	1.34	0.234	0	-12.959
Total	Before LD	237.70	200.205	3.14	1.096	19.7	13.559
	After LD	237.70	228.850	5.55	3.300	0	0
	Change	0	28.645	2.41	2.204	-19.7	-13.559

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and crown density of forest stand and so on The average wood, the dominance wood, the pressed wood and the wood with diameter 1.0 cm are selected to measure the biomass. The delamination incision method is used to measure the stock biomass, the delamination standard method or sample branch method is used to measure the biomass of branches and leaves. The underground part of biomass is determined as follows (Wu and Feng, 1995): confirming the mean nutrition boundary of individual plant, digging up all the underground part in layers, then weighting them in term of root stake, thick root (>2.0 cm), middle root (1.0~2.0 cm) and radicel (<1.0 cm).

The shrub layer observation: Setting up 3 sample squares with 5 × 5 m in the representative section of area or in standard sample area to investigate and measure the types and cover degree of shrub, the total of sample square is 48 in the experiment field. The fresh weight of every plant is weighted in term of aboveground part, underground part and apparatus. The root weight is calculated from the ratio of aboveground part and underground part.

The herbage layer observation: Setting up 3 sample squares with 1 × 1 m in the standard sample area or grass slope to weight in term of aboveground part and underground part by "the harvest method of sample square", the total of sample square is 46 in the experiment field.

The fresh weight is weighted in term of types and apparatus. Dry samples of apparatus are pick-up in subsection to drying in the drying cabinet with 80°C, then weight. The ratio of containing water is calculated, the dry weight of apparatus in unit area are calculated (that is, the biomass) (Liu *et al*., 1997).

The biomass calculation: Considering the characteristics of vegetation in the experiment area and accumulated data in traditional biomass measure and calculation, the experience formula are used to calculate the biomass and growth of community as follows (Wang *et al*., 2004).

The arbor layer:

$$B = 0.00003396D^2H$$

$$P = 0.000012046\ (D^2H)\ ^*0.6253$$

where,

B = The biomass (dry weight) (t/hm^2)
P = The growth (dry weight) (t/hm^2)
D = The bosom diameter of tree (cm)
H = The tree highness (m)

The herbage layer:

$$B_{mg} = \frac{B_{ma}}{B_a} \sum_{i=1}^{n} F_i$$

where, B_{mg} is biomass in herbage layer (dry weight) (t/hm^2), B_{ma} is maximum biomass in herbage layer (dry weight) (t/hm^2), F_a is maximum chubbiness ratio, F_i is chubbiness of pant i and n is the number of species in

Table 3: The results of biomass measure and calculation fore-and-aft land consolidation

Type of plant	Total area hm^2		Average biomass t/hm^2		Total biomass t		(%)		Biomass change t
	Before LD	After LD	Before LD	After LD	Before LD	After LD	Before LD	After LD	
Open forest	3.140	3.14	19.870	19.870	62.392	62.392	6.79	4.16	0
Aspen forest	0.000	2.41	0.000	52.042	0.000	125.421	0	8.37	125.421
Waste grassplot	13.559	0.00	1.352	0.000	18.332	0.000	2	0	-18.332
Rice	70.170	124.78	6.010	7.210	421.722	899.664	45.92	60.04	477.942
Dry-land crop	130.035	104.07	3.200	3.950	416.112	411.077	45.30	27.43	-5.035
Total biomass					918.558	1498.554	100	100	579.996

herbage layer. The chubbiness ratio is the product of relative highness (%), cover degree (%) and frequency (%) of plant. This method is named the chubbiness method. The biomass of herbage layer can be also measured by the harvestry method.

RESULTS AND ANALYSIS

The results of measure and calculation: With the investigation of sample plot, the biomass fore-and-aft land consolidation is measured and calculated for the experiment area on the methods described in above section (Table 3).

Analysis: The result (Table 3) shows that the biomass is increased 580 t after land consolidation in the experiment area, meaning the impression of land consolidation is remarkable in general. The ecological effects will be resulted from this remarkable increase of regional biomass and a dynamic balance is related to the ecological succession induced by these effects.
The results of monomial analysis are as follows:

- The biomass of sparse forest is no changed fore-and aft land consolidation, but its ratio of biomass is reduced down 2.5% and its ecological influence is slightly weakened.
- The biomass sum of manpower forest and sparse forest is increased up 6% after land consolidation, so that the total ecological influence of woodland is enhanced.
- The waste grassplot is disappear of land consolidation, so that its ecological influence.
- The total biomass of dry-land crop is all most no change, but its influence is reduced down 17.87%.
- The total biomass of rice is increased up 477.94 t after land consolidation, account of 82.4% of increased amount and its total ecological influence is up to 14.12%.

DISCUSSION

The stability of ecological pyramid: According to the vulnerability of artificial ecosystem, the biomass in all the trophic levels of ecosystem will be retained to balance in land consolidation to vindicate the stability of ecosystem. In the experimental area, the wasteland is regulated to farmland and parts of dry-land are adjusted to paddy field, following to the planning and design of land consolidation. The area of protection forest is increased and so does plant biomass. The biomass of first trophic level (that is primary productivity) of ecosystem is accordingly increased. The increase of primary productivity will provide a lot of food to customers in the second trophic level of the ecosystem such as rabbit, rat, squirrel, bird, wild boar and so on. So the secondary productivity will also increased and provided more the food to the customers in third trophic level such as snake, eagle and so on. But the area of sparse forest and protection forest is not enough large and the biomass of primary customers is not enough to feed the large animals, there are no plenty of species and quantity of the secondary customers. The regulation and control of feedback mechanism between the primary and secondary customers is mainly take place among the beasties in the ecosystem. Compared with the ecosystem before land consolidation, there is no obvious change on the feedback mechanism of regulation and control in the ecosystem after land consolidation. So the stability of ecological pyramid seemed more and less unaffected by land consolidation.

Intensity of soil erosion: In general, the intensity of soil erosion is related to the forest coverage, but the biomass is also one of important effecting factors. The active and negative influences of soil erosion are induced by the biomass change fore-and-aft land consolidation to the intensity of soil erosion. The biomass increase will reduce the intensity of soil erosion and vice versa. The biomass change is different in spatial-temporal distribution and its influence is complex in experimental area. First of all, the intensity will be enhanced by the biomass decrease in the period of ground leveling of land consolidation. Secondly, the intensity enhance will be induced in the places translated from shrub and wasteland to farmland in land consolidation. Thirdly, the intensity will be reduced by the biomass increase by the construction of protection forest of land consolidation. Fourthly, the intensity will be reduced by the biomass increase though the improvement of production condition. The results show, the total biomass is increased though land consolidation, so the intensity of soil erosion is decreased in the experimental area.

Intensity of greenhouse effect: The biomass change affects directly and indirectly to the greenhouse effect in an area. After land consolidation, the biomass increases 580 t in experimental area. The added primary producers will deplete a great deal of CO_2 and release O_2. The abundance of CO_2 in atmosphere will be reduced and so do the intensity of greenhouse effect in the area. With the condition improvement of life and production, human activity is more active and other resources of greenhouse gasses will enhance.

Harmony of ecological landscape: The types of ecological landscape are influenced by the biomass change and ecological service is also affected in the region. The analysis results show that the types of ecosystem are changed obviously. After land consolidation, the waste grassplot is disappeared, its biomass reduced from 18.332 to 0 t. Inversely, aspen forest is appeared, its biomass increased from 0 to 125.421 t. These change of ecosystem types reflected obviously on the ecological landscape. Land consolidation also changes the model of agricultural landscape. Four types of engineering are included in land consolidation, that is, ground leveling engineering, road construction engineering, agricultural hydraulic engineering and protection forest engineering. After land consolidation, the farmland plots are regulated to rectangle, the roads are planed to pane, the trees are planted on rows and the channels are distributed along the main roads. The integrated ecological landscape after land consolidation is harmony.

CONCLUSION

The biomass research is one of the focuses in academe and many achievements are taken out. The last achievements are mainly focused on the methods of measure and calculation of biomass, but the relationships between the biomass change and ecological influence in land consolidation. Based on the achievements of biomass and land consolidation, the biomass change and its ecological influence are discussed in land consolidation. The results show:

- The structure and function of regional ecosystem will be changed by land consolidation and the biomass will be changed accordingly.
- Marked ecological influence will be induced from the biomass change, not only the natural ecosystem, but also the human ecosystem.

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