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Research Article

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River Ecosystem and Floristic Characterization of Riparian at the Songji River, Sacheon-ci, Korea

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Abstract This study is to investigate the river ecosystem and the riparian vegetation on the Songji River at three regions. The riparian areas of both the river banks are dominated by mixed sediment and the vegetation is composed of herbs, shrub, and trees. The low water's edge vegetation and flood way vegetation at upper region of the Songji River were naturally formed various vegetation communities by natural erosion. Land use in riparian zones at upper area was partly bush or grassland as natural floodplain. Whereas, land uses in riparian zones river levee at middle and low areas were arable land, urban, residential mixed. Left and right riparian areas at upper area were distributed Pinaceae vegetation (Pinus densiflora, and Pinus rigida) and Fegaceae vegetation (Castanea crenata, Quercus dentata, and Quercus variabilis). Left and right riparian areas at middle region were distributed Polygonaceae, Cruciferae, Onagraceae, and Compositae vegetation. There were occurred in Equisetum arvense, Persicaria sieboldi, Trifolium repens, Oenothera odorata, Phragmites japonica, and Zoysia japonica at low region. According to the existing phytosociological data, 27 families, 65 genera, 71 species, 9 varieties, 21 associations, and 13 communities have been identified.

Keywords Phytosociological data, riparian vegetation, Songji River, vegetation communities

Introduction

Plants living in wetlands must be able to survive both inundation and drying as water levels may fluctuate greatly seasonally. Other plants are adapted to live predominantly beneath the water's surface (submerging), others float on the surface (floating), while others emerge from water with stiff stems holding the plants leaves above the water (emergent). River bank vegetation, ecologically termed as riparian flora which is highly dynamic, linking terrestrial and aquatic habitat, under the influence of a waterway, such as rivulet banks or riverbanks, represented by a particular type of vegetation that grows along the sides of rivers are called the river's riparian zone [1].

The riparian zone is the place where aquatic systems merge with the terrestrial environment. Virtually all rainwater runoff must pass through the zone before moving into adjacent aquatic/estuarine systems. It has been termed the terrestrial/aquatic interface. They typically occupy a small fraction of the landscape, but they often play a disproportionately important role in controlling water and chemical exchange between surrounding lands and stream systems [2]. Thus, riparian vegetation is increasingly being recognized for its importance in influencing the hydrology and morphology of fluvial systems [3].

The Songji River is started at the low mountains and ends at the Pacific Ocean. The river watershed is made up of forests, streams, fields, wetlands, ponds, and other ecosystems that provide the perfect habitat for an abundance of plants and animals. The river channels, back cove areas, tributaries, and the riparian land along the river edge serve as host to thousands of plant and animal species. Probably one of the most important roles of riparian vegetation in this river is as a buffer between terrestrial activities and aquatic ecosystems. The many plants that grow along the banks of this river and her tributaries play an important role in the diverse ecosystems the river supports. Not only do the plants rely on the Songji River for water, but they also play an important role in nutrient and water conservation, and their presence controls soil erosion along the banks. The entire upper plains of the Songji River, including the area between two reservoirs, used to be covered with moderate deciduous forest made up of pine trees and other species. Unfortunately, middle and low regions have now been

deforested and heavily cultivated. Water can converge on riparian zones from many directions. Precipitation falls on riparian zones. Some precipitation is intercepted by plant foliage and evaporated back to the atmosphere, but most of it reaches the soil. Overland and subsurface runoff from uplands flows laterally across riparian zones to streams. Overland runoff is generated when infiltration is limited by low soil permeability or its saturation. When forests are destroyed, the atmosphere, water bodies and the water table are all affected. Trees absorb and retain water in their roots. A large part of the water that circulates in the ecosystem of rainforests remains inside the plants. Some of this moisture is transpired into the atmosphere. When this process is broken, the atmosphere and water bodies begin to dry out. The watershed potential is compromised and less water will run through the rivers. Smaller lakes and streams that take water from these larger water bodies dry up. Riparian zones of Middle and low regions have been destructed in the Songji River. The local level is where deforestation has the most immediate effect. This disrupts the natural flooding cycles, reduces flows, drains wetlands, cuts rivers off from their floodplains, and inundates riparian habitats, resulting in the destruction of species, the intensification of floods and a threat to livelihoods in the long term [4].

The purpose of this study is to investigate river ecosystem and the flora on the Songji River at three regions. Therefore, this survey recorded material significance for the future appears in the environment to restore or improve the problem may be.

Materials and Methods

Surveyed Regions

This study was carried out on the Songji River, located at Yonghyeon-myeon province (upper region: 35°011′014″N/128°100′014″E, low region: 35°012′794″N/128°049′459″E), Sacheon-ci in Korea (Fig. 1). The river is located to the northern east of the city of Sacheon-ci. The river is approximately 4.85 kilometers in length with a varying width of between 2.3 and 38.6 meters. The flora and vegetation on the Songji River were investigated at three regions and adjacent areas during four seasons.

Floristic analysis

Three sectors of the riparian vegetation on the Songji River were chosen to study. At these places, a floristic survey of trees, shrubs, herbs, grass and aquatic species was performed by least count quadrat method. Each species was collected, mounted, labeled, and systematically arranged in a herbarium. The system of plant classification system was followed by Lee [5]. Naturalized plants were followed by Korea National Arboretum [6]. Abundance and cover degree are usually estimated together in a single combined estimation or cover-abundance scale from Braun-Blanquet [7]. In order to relate the model to the field situation in which usually Braun-Blanquet figures are recorded, the % occupancy figures were transformed in to the ordinal transform scale from 1 (one or few individuals) to 9 (75~100% cover of total plot area, irrespective of number of individuals) [8, 9]. The relative net contribution degree (r-NCD) was obtained by summing up the NCD values for those species belonging to particular taxa under consideration [10].

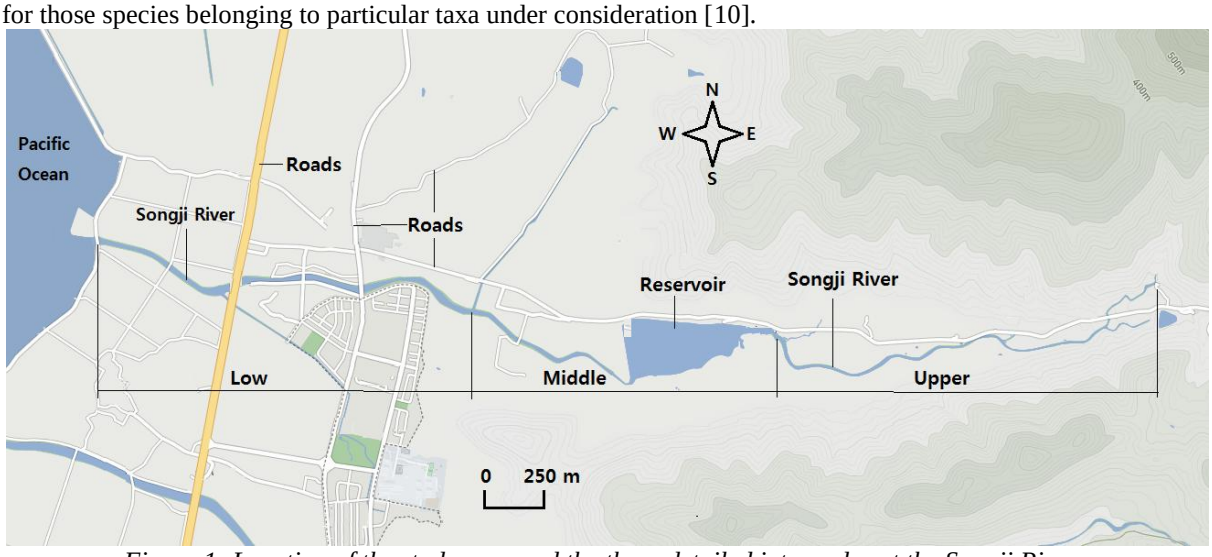

Figure 1: Location of the study area and the three detailed internodes at the Songji River.

Index of degree of river structure

The three regions of Songji River were divided by the geographic location with considering length of the river and river morphology. Index of degree of river naturality according to the environment of river was also analyzed according to Table 1. River terminology was followed by Hutchinson [11]. The test for biochemical oxygen demand (BOD) is a bioassay procedure that measures the oxygen consumed by bacteria from the decomposition of organic matter [12]. The change in DO concentration is measured over a given period of time

in water samples at a specified temperature. The method for BOD was used to a standard method of the American Public Health Association (APHA) and is approved by the U.S. Environmental Protection Agency [13].

Table 1: Index of degree of river naturality according to the environmental factors

Item	Estimated index and scores				
	1	**2**	**3**	**4**	**5**
The low water's edge vegetation	Naturally formed a variety of vegetation communities	Naturally formed various vegetation communities by natural erosion (sediment exposure) were absent	Natural weeds, shrubs, and mixed	Artificial vegetation composition	Vegetation blocked by stonework etc.
Flood way vegetation	Naturally formed a variety of vegetation communities	Naturally formed various vegetation communities by natural erosion (sand bar) were absent	Both of natural vegetation and artificial vegetation	Artificial vegetation with Parks, lawns, and so on	Remove vegetation artificially
Land use in riparian zones within river levee	Bush or grassland as natural floodplain	Arable land (paddy fields, orchards)	Arable land, urban, residential mixed	About 1/2 urban, residential mixed	1/2 or more urban, residential
Land use in flood plains beyond river levee	State of nature without artificial vegetation, manmade structures	Arable land or artificial vegetation	Artificial vegetation or natural vegetation mixed	About 1/2 park facilities, playground facilities	Impervious man-made structures, parking, etc.
Transverse direction of artificial structures	Absent	Bypass reservoir or slope waterway reservoir	Fish migration reservoir	Reservoir of height 0.3-0.4 m, fish migration difficulty	Fish move completely blocked
Water quality (BOD)	Class 1 (crystal clear)	Class 2 (clear relatively)	Class 3 (tan, the bottom green algae)	Class 4 (blackish brown, the floor is not looked)	Class 5 (an ink color, odor)
Sleep width /river width ratio	20% or more	20 ~ 10%	10 ~ 5%	5 ~ 1 %	Less than 1%

Results

Upper Region (upstream)

The river width at this region is about 2.3 m. The riparian areas of both the river banks are dominated by mixed sediment and the vegetation is composed of herbs, shrub, trees, climbers and macrophytes. The low water's edge vegetation and flood way vegetation were naturally formed various vegetation communities by natural erosion (sediment exposure) (Table 2). Land use in riparian zones was partly bush or grassland as natural floodplain. Most land uses of flood plains beyond river levee were state of nature without artificial vegetation and manmade structures. Transverse direction of artificial structures was one reservoir of above height 25.0 m. Thus fish could not move completely blocked. The average value of BOD was 2.67 mg/l. The oxygen-demand parameter BOD at upper region was within acceptable levels. The ratio of sleep width/river width was 5-10%. The value for index of degree of river naturality according to the environment factors was a mean of 1.857.

Table 2: The degrees of river naturality according to the environmental factors at the Songji River

Region	The low water's edge vegetation	Flood way vegetation	Land use in riparian zones within river levee	Land use in flood plains beyond river levee	Transverse direction of artificial structures	Water quality (BOD)	Sleep width /river width ratio	Mean
Upper	2	2	1	1	2	2	3	1.857
Middle	2	3	3	3	1	2	3	2.429
Low	2	3	3	3	1	3	4	2.714

Riparian vegetation provides habitat for many wildlife species (Table 3). At total area, the application of the Braun-Blanquet approach for plant classification in this area is presented in the article. According to the existing phytosociological data, 27 families, 65 genera, 71 species, 9 varieties, 21 associations, and 13 communities have been identified. 35 species was found in this upper region. Left and right riparian areas at upper area were distributed Pinaceae vegetation (*Pinus densiflora*, and *Pinus rigida*) and Fegaceae vegetation (*Castanea crenata*, *Quercus dentata*, and *Quercus variabilis*). Riverbed area was dominated by *Pueraria thunbergiana* community. Dominant species in flood plains were *Equisetum arvense*, *Trifolium repens*, and *Zoysia japonica*. The survey region was a total of 35 taxa, including 21 families, 32 species, and three varieties. Naturalized plants were seven species. In some cases the quantitative and qualitative levels fifer considerably. The total transformed Braun-Blanquet value and r-NCD at upper area were 74 and 925, respectively.

Table 3: List of vascular plants and r-NCD at the Songji River

Family	Species	Region			Invaded plant	r-NCD		
		Upper	Middle	Low		Upper	Middle	Low
Equisetaceae	*Equisetum arvense* L.	4	3	4		50.0	37.5	50.0
Ginkoaceae	*Ginko biloba L.*	1	1			12.5	12.5	0
Pinaceae	*Pinus densiflora S. et Z.*	3				37.5	0	0
	Pinus **thunbergii** *Parl.*	4				50.0	0	0
Salicaceae	*Salix gracilistyla Miq.*	2				25.0	0	0
Fegaceae	*Castanea crenata Sieb. Et Zucc*	3				375	0	0
	Quercus dentata Thunb. ex Murray	2				25.0	0	0
	Quercus variabilis Blume	2				25.0	0	0
Moraceae	*Morus alba L.*	1	1			12.5	12.5	0
Cannabinaceae	*Humulus japonicus S. et Z.*	2				25.0	0	0
Polygonaceae	*Persicaria blumei Gross*		4	2		0	50.0	25.0
	Persicaria sieboldi Ohki			4		0	0	50.0
	Persicaria thunbergii H. Gross		2			0	25.0	0
	Rumex acetocella L.		2	3	NAT	0	25.0	37.5
	Rumex acetosa L.	2	2			25.0	25.0	0
	Rumex conglomeratus Murr.	2	2	3	NAT	25.0	25.0	37.5
	Rumex crispus L.		3	3	NAT	0	37.5	37.5
Chenopodiaceae	*Chenopodium album var. centrorubrum Makino*	2	3	3		25.0	37.5	37.5
	Chenopodium ficifolium Smith		2	2	NAT	0	25.0	25.0
Amaranthaceae	*Amaranthus lividus L.*		2		NAT	0	25.0	0
Phytolaccaceae	*Phytolacca americana L.*	1			NAT	12.5	0	0

Ranunculaceae	*Ranunculus japonicus Thunb.*		2	2		0	25.0	25.0
Cruciferae	*Capsella bursa-pastoris (L.) Medicus*		2	2		0	25.0	25.0
	Capsella flexuosa With.		2	2		0	25.0	25.0
	Lepidium apetalum Willd.		3	3	NAT	0	37.5	37.5
	Lepidium virginicum L.		2	3	NAT	0	25.0	37.5
	Rorippa indica (L.) Hiern		2	3		0	25.0	37.5
	Thlaspi arvense L.		2	2	NAT	0	25.0	25.0
Rosaceae	*Potentilla fragarioides var. major Max.*	3				37.5	0	0
	Prunus serrulata var. spontanea (Max.) Wils.		1	1		0	12.5	12.5
	Rosa multiflora Thunb.	2	2			25.0	25.0	0
Leguminosae	*Amorpha fruticosa L.*	2	2	2	NAT	25.0	25.0	25.0
	Amphicarpaea edgeworthii var. trisperma Ohwi		3	2		0	37.5	25.0
	Astragalus sinicus L.		1		NAT	0	12.5	0
	Kummerowia striata (Thunb.) Schindl.		2	2		0	25.0	25.0
	Pueraria thunbergiana Benth.	5				62.5	0	0
	Trifolium pratense L.	3	3	2	NAT	37.5	37.5	25.0
	Trifolium repens L.	2	2	4	NAT	25.0	25.0	50.0
Aceraceae	*Acer pseudo-sibolianum (Paxton) Kom.*	1				12.5	0	0
Oxalidaceae	*Oxalis corniculata L.*	1	2	1		12.5	25.0	12.5
Violaceae	*Viola mandshurica W. Becker*	2				25.0	0	0
Onagraceae	*Oenothera odorata Jacq.*	2	4	4	NAT	25.0	50.0	50.0
Umbelliferae	*Oenanthe javanica (Bl.) DC.*	2	3			25.0	37.5	0
Oleaceae	*Forsythia koreana Nakai*		2	2		0	25.0	25.0
Plantaginaceae	*Plantago asiatica L.*	2	2	3		25.0	25.0	37.5
Caprifoliaceae	*Lonicera japonica Thunb.*	1				12.5	0	0
Compositae	*Ambrosia artemisiifolia var. elatior Descourtils*			2	NAT	0	0	25.0
	Artemisia princeps Pampan.	2	4	4		25.0	50.0	50.0
	Artemisia selengensis Turcz.		2	2		0	25.0	25.0
	Aster ciliosus Kitamura		1			0	12.5	0
	Bidens bipinnata L.		2	1		0	25.0	12.5
	Bidens frondosa L.		2	2	NAT	0	25.0	25.0
	Cirsium japonicum var. ussuriense Kitamura		1			0	12.5	0
	Cosmos bipinnatus Cav.		3	4	NAT	0	37.5	50.0
	Conyza canadensis L.		1		NAT	0	12.5	0
	Erechtites hieracifolia Raf.		2	3	NAT	0	25.0	37.5
	Erigeron annuas (L.) Pers.		2	2	NAT	0	25.0	25.0
	Galingosa ciliate Blake	1			NAT	12.5	0	0
	Sonchus asper (L.) Hill		2	2		0	25.0	25.0
	Taraxacum officinale Weber		1	1	NAT	0	12.5	12.5
	Xanthium strumarium L.		1	1	NAT	0	12.5	12.5
Typhaceae	*Typha orientalis Presl*		2			0	25.0	0
Gramineae	*Agropyron tsukusinense (Honda) Ohwi*	2	2			25.0	25.0	0

	Avena fatua L.		1	1	NAT	0	12.5	12.5
	Argostis clavata var. nukabo Ohwi.		1			0	12.5	0
	Bromus japonicus Thunb.		2			0	25.0	0
	Cymbopogon tortilis var. goeringii Hand-Mazz.		1			0	12.5	0
	Digitaria sanguinalis (L.) Scop.	1	3			12.5	37.5	0
	Echinochloa crus-galli (L.) Beauv.		2			0	25.0	0
	Eleusine indica (L.) Gaertner		1			0	12.5	0
	Festuca arundinacea Schreb.		3	2		0	37.5	25.0
	Imperata cylindrica var. koenigii Durand et Schinz			1		0	0	12.5
	Miscanthus sacchariflorus Benth.	2	3	4		25.0	37.5	50.0
	Miscanthus sinensis var. purpurascens Rendle	2	2	2		25.0	25.0	25.0
	Phragmites japonica Steud.		3	6		0	37.5	75.0
	Poa sphondylodes Trin.		1			0	12.5	0
	Setaria viridis (L.) Beauv.	2	3	3		25.0	37.5	37.5
	Zoysia japonica Steud.	3	5	5		37.5	62.5	62.5
Cyperaceae	*Cyperus amuricus Max*		1	2		0	12.5	25.0
	Cyperus difformis L.		1			0	12.5	0

NAT: Naturalized plants.

Middle Region (middle-stream)

The river width at the region is about 12.7 m. The low water's edge vegetation was naturally formed various vegetation communities by natural erosion (sediment exposure) (Table 3). The flood way vegetation was both of natural vegetation and artificial vegetation. Land uses in riparian zones river levee were arable land, urban, residential mixed. Land use in flood plains beyond river levee was artificial vegetation or natural vegetation mixed. Transverse direction of artificial structures was absent. The average value of BOD was 3.15 mg/l. The oxygen-demand parameter BOD was within acceptable levels. The ratio of sleep width/river width was 5-10%. The value for index of degree of river naturality according to the environment factors was a mean of 2.429.

Left and right riparian areas were distributed Polygonaceae vegetation (*Persicaria blumei*, *Persicaria thunbergii*, *Rumex acetocella*, and *Rumex acetosa*), Cruciferae vegetation (seven species including *Lepidium apetalum*), Onagraceae (*Oenothera odorata*), and Compositae vegetation (*Artemisia princeps*) (Table 3). Land use in flood plains beyond river levee was dominated Gramineae vegetation (*Zoysia japonica*). Other phyla were occasionally recorded in low densities. The survey region was a total of 63 taxa, including 18 families, 57 species, and 6 varieties. Naturalized plants were 21 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 131 and 1,638, respectively.

Low Region (downstream)

The river width at the region was about 38.6 m. The low water's edge vegetation was naturally formed various vegetation communities by natural erosion (sediment exposure) (Table 3). The flood way vegetation was both of natural vegetation and artificial vegetation. Land uses in riparian zones river levee were arable land, urban, residential mixed. Land use in flood plains beyond river levee was artificial vegetation or natural vegetation mixed. The average value of BOD was 4.33 mg/l. The oxygen-demand parameter BOD was not good at low region. The ratio of sleep width/river width was 1-5%. The value for index of degree of river naturality according to the environment factors was a mean of 2.714.

There were occurred in *Equisetum arvense*, *Persicaria sieboldi*, *Trifolium repens*, *Oenothera odorata*, *Phragmites japonica*, and *Zoysia japonica* (Table 3). They dominated over the other phyla and were mainly recorded in high densities during summer and autumn. The survey region was a total of 45 taxa, including 14 families, 40 species, and 5 varieties. Naturalized plants were 19 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 114 and 1,425, respectively.

Discussion

Riparian flora in the river areas are influencing the river bank health in a numbers of ways [1]. First, roots of

some grasses and macrophytes protect the river banks. Second, plants such as grasses make the soil fertile by trapping the nutrients during seasonal flood. Third, riparian flora provided many services to wildlife, human beings and to the environment. Vegetation ecology, the study of the plant cover and its relationships with the environment, also called synecology, is a complex scientific undertaking, both regarding the overwhelming variation of its object of study in space and time, and its intricate interactions with abiotic and biotic factors. Some of the most common plants are cattails, water lilies, arrowheads, and rushes [10]. Riparian area at upper region of the Songji River is not wider than those of middle and low regions. Thus, many species are not distributed in this region. Although it is often difficult to determine its exact boundaries on ecosystem, the riparian is recognized producers as an important ecological value of vegetation. The Songji River was characterized a lot of riparian at ten year ago. Generally, the Pacific side of Korea has heavy rain between June and July (rainy season) or August and October (Typhoons) in a short time [14]. The heavy storms results in widespread landslides and extensive flood discharges [15]. Suddenly flood events from the mountains have influenced riparian vegetation and sand dunes directly through inundation, mechanical damage, and indirectly through changes in channel morphology. Many cement blocks at low region of the Songji River were creating instead river grasslands by the Direct-stream Rivers Project because of most rain falling period between June and August. This artificial action reduced the water's natural filtration action and eliminated the habitat of many animals. Thus there was decreased the number of species in low region. This decreasing trend was supported mainly by an increase of artificial disturbances such as road or house construction at flood plains beyond river levee. The floodplains of the Songji River have been converted to agricultural or horticultural fields, housing or industrial areas, restricting the river bed to a small channel; although the levees can be set back to some degree, the historic floodplains cannot realistically be reclaimed by the river. Humans are affected on rivers directly or indirectly by changing land use in river morphology. They also simultaneously accelerate and decelerate fluxes of water, sediments, and nutrients on a scale that exceeds natural filtration action [16]. Awareness of current conditions and relationships between land uses and resource goals is essential for successful restoration of riparian systems.

Conclusions

The floristic characterization of riparian at the Songji River during 2015 season was identified with a total of 27 families, 65 genera, 71 species, 9 varieties, 21 associations, and 13 communities have been identified. Recently many riparian areas of Songji River have been lost or degraded for commercial and industrial developments. Thus, monitoring for biological diversity of plant species of this river is necessary for an adaptive management approach and the successful implementation of ecosystem management.

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