Effects of partial restoration practiced by a method suitable for the riverine environment in Korea

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Abstract

Korean rivers and their surrounding environments have been used excessively for rice production in the past and for construction of urban areas to expropriate the rapidly increasing population in recent years. The rivers not only experience severer fluctuation of water level due to the typical continental climate but also maintain faster water current due to steep slope compared with those in the other countries. In order to improve the naturalness in the river with such conditions, a partial restoration, which achieves both physical and biological stability simultaneously, was practiced. Terra cottem, which was applied to supplement water lost due to intense heat on concrete block introduced artificially to increase physical stability at flooding, increased water-holding capacity and thereby contributed to increase plant survival and growth. Further, the restoration practiced by applying the material displayed the restoration effects by increasing vegetation coverage and species diversity, and by changing species composition similarly to that of the control site. These results implied a possibility that a restoration improving naturalness can be realized by introducing vegetation in a state maintaining the physical stability relied on artificial facilities.

Key words: Korean rivers, Partial restoration, Species diversity, Species composition, Terra cottem, Vegetation coverage. Water-holding capacity

Introduction

Riparian landscapes including a river ecosystem and its surrounding environment hardly holds its original feature owing to excessive use for that. Riparian landscapes have been usually managed in terms of use and disaster protection to date. But its importance as a natural environment is reevaluated in these days (Petts and Calow 1995).

Riparian ecosystems are spatially and

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temporally dynamic and are shaped by fluvial geomorphic processes, there are, therefore, physical and biological links between terrestrial and aquatic environments and biotopes in which animals may seek refuge and food, while enriching the soil in detritus (Gregory et al. 1991). Riparian ecosystems usually support higher species richness and densities of wildlife than do other nearby ecosystems (Johnson and Simpson 1971, Carothers et al. 1974). Riparian vegetation detains erosion materials, thus decreasing the amount of solids in suspension in the watercourses and improving the quality of the water (Howard-Williams et al. 1986, Cooke and Cooper 1988, Pinay and Decamps 1988, Fustec et al. 1991, Haycock and Burt 1990, 1991). It slows down the flow of torrential rains and collects the material carried, reducing the effects downstream. Furthermore, the highly developed root systems reinforce the banks of the streams (Salinas and Guirado 2002).

All these advantages, together with the considerable enhancement of the landscape that this vegetation affords, justify considering this type of vegetation as being of primary importance (Salinas and Guirado 2002). The maintenance and/or restoration of vegetation thus deserve to be given priority in land management projects.

Habitat restoration is currently a major focus in the field of environmental science and generally refers to the reestablishment of processes and functions of biological, chemical, and physical linkages between aquatic, riparian, and associated terrestrial ecosystems (Kaffman et al. 1997). Restoration is the process of returning a river (or assisting its recovery) to a condition in which it can function ecologically in a self-sustaining way, more nearly resembling its former function prior to human-induced disturbance (Cairns 1989, Bisson et al. 1992, Sear 1994). Taking a dynamic, co-evolutionary view of rivers and/or streams, restoration can be defined as the act of relaxing human constraints on the development of natural patterns of diversity (Frissell and Bayles 1996, Ebersole et al. 1997). In this view, a restored ecosystem does not necessarily return to a single ideal and stable state (i.e. pristine) but is free to express a range of natural successional trajectories and states, as constrained by the historical biological and physical characteristics of the river and its natural disturbance regime (Frissell and Ralph 1998). That is, restoration measures should not focus on directly recreating natural structures or stages, but on identifying and reestablishing the conditions under which natural states create themselves. In fact, European countries pursue restoration, in which the river itself recovers nature, by leaving it in natural process after extending the width of river (Hey 1995).

In Asian countries where people live on rice, most flood plains of rivers and/or streams were transformed to rice fields in the past and super banks were constructed nearby waterway to prevent flooding damage. Therefore, widths of most rivers and/or streams were reduced sharply. Further, much of those rice fields were not only again transformed to urbanized areas including residential area, but also meandering and complex channels were changed to straight and monotonous ones in urban areas. In such continuing transformation processes, riverside communities have been greatly degenerated or destroyed by tree cutting, the introduction of exotic species, the diversion and channeling of water for agriculture, and the use of river beds and shores for cultivation or even roads.

In order to restore a degraded ecosystem like this, we have to get information from various scientific principles, because holistic and synthetic measures have to be prepared (Aber 1987). First of all, we have to prepare such measures by obtaining diverse ecological information including physical factors as well as biological factors of a habitat, which we intend to restore (Aber 1987, MacMahon 1987). In particular, we have to get plentiful field information the area which will be restored, because restoration efforts have to be practiced in the field (Hough 1984).

An attempt that intends to create the natural river by applying the ecological engineering technique has appeared frequently in Korea since the 1990's (KICT 2002). Restoration is usually focused on the waterfront in such restoration projects. However, true effect of restoration can be achieved when the spatial range is expanded to flood plain, weir, and furthermore, surrounding environment (Frissell and Ralph 1998). Therefore, extension of the spatial range for restoration subject is required in the restoration project to be practiced in the future. But rivers experience very severe fluctuation of water levels in Korea with the typical continental climate (Ahn 1995). Moreover, topographical characteristics of mountainous land that occupies a large area of about 65% makes a steep slope and thereby leads to rapid water flow. Those natural characteristics and the excessive land use practiced around the river make true restoration of a river hard to realize.

This study aims in a restoration, which achieves both physical and biological stability simultaneously in the Korean river with such condition.

Methods

Laboratory experiments were carried out in a green house. A concrete wall with holes of 10 cm in diameter was used as substitute of artificial waterfront protection facilities. When the facilities are exposed to the intense sunlight in the summer, its temperature increases greatly and severe water loss is expected due to that. This study chose water holding material called as Terra cottem (abbreviated as TC hereafter) as a measure for the environmental stress. Above mentioned experimental facilities were classified into four TC contents of control, 1%, 2%, and 3% treatments and three water supply intervals of 1 week, 2 week, and 3 week. Each treatment has three duplicates. The effects of TC were evaluated by growth response of sample plants. Plant growth was measured by leaf area and branch growths. *Salix gracilistyla*, *S. koreensis* and *Spiraea prunifolia* var. *simplicifolia* were chosen as sample plants. The former species grow in waterfront or floodplains close to waterways and the latter two plants grow in flood plains far from the waterway. They would therefore show different responses on the environmental conditions, such as moisture content, disturbance cycle, etc different according to distances from the waterway. Leaf area was calculated by applying ellipse's equation from leaf length and breadth. Total leaf area was obtained by duplicating the number of leaves to the leaf area. Leaf length and breadth were measured by calipers with 0.05 mm presion. Branch length was measured by measuring tape.

Field experiments were carried out in the Dongmun stream located in Paju, Gyunggi province in central western Korea. Sample plants cultivated in textile pot (10 cm and 15 cm in diameter and height, respectively) with different TC contents were planted in the holes, which were made on a concrete wall constructed for waterfront protection. Mortality of sample plants was measured by the ratio of the alive plants to the planted plants in one year after plantation. Plant growth was determined by measuring branch length by applying the same method as the laboratory experiment. Vegetation survey for monitoring was carried out by recording cover class of Braun-Blanquet (1964) of plants appearing in quadrat of 2 m x 2 m installed randomly. Ordinal cover of Braun-Blanquet was converted to the median value of percent cover range in each cover class and then subjected to Detrended Correspondence Analysis (DCA; Hill 1979). Species diversity was compared by rank-abundance curves, which graphically depict patterns of species diversity and dominance (Magurran, 1988).

Results

Laboratory experiment

Growth coefficients obtained from growth curves of sample plants were used as a tool to compare plant growth among plots with different TC contents and water supply intervals. The higher TC contents were, the larger growth coefficients were in all sample plants and plots with different water supply intervals (Tables 1 and 2). Moreover, the longer water supply intervals were, the larger relative growth coefficients were. That is to say, TC played a more important role as the water supply intervals become longer.

The water holding effects of TC were evaluated by comparing changes of water contents of soil with different TC contents after water withdrawal. The more the TC contents, the slower the water content reduction was, and thereby reflected improvement of water-holding capacity by TC (Fig. 1).

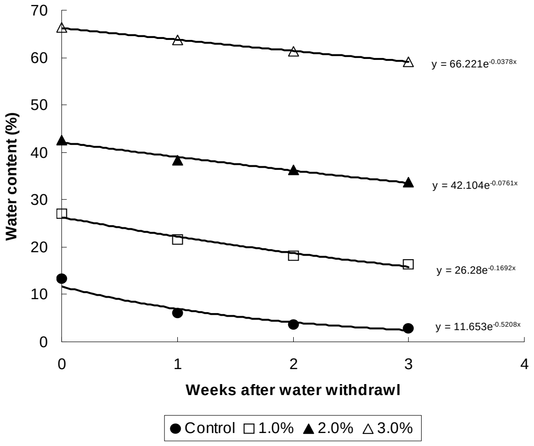

Fig. 1. Changes of water content of soil with different Terra cottem contents with the lapse of time after water withdrawal. Equations on the graph indicate regression equation of reduction curves of water content. The larger the regression coefficients, the faster the water contents are reduced.

Table 1. Branch growth coefficients (GC) and the relative index (RI) to the control plot of sample plants in each treatment. Sg: *S. gracilistyla*, Sk: *S. koreensis*, Sp: *Spiraea prunifolia* var. *simplicifolia*

Water supply interval	Terra cottem content	Sg		Sk		Sp	
		GC	RI	GC	RI	GC	RI
1 week	Control	4.0	100.0	18.7	100.0	16.8	100.0
	1.0 %	5.5	136.0	21.0	112.0	18.3	109.2
	2.0 %	6.5	160.9	21.8	116.4	24.5	145.9
	3.0 %	7.7	190.1	31.5	168.2	35.7	212.7
2 week	Control	2.6	100.0	10.2	100.0	13.3	100.0
	1.0 %	3.2	125.1	12.6	123.8	20.5	154.3
	2.0 %	4.7	182.2	15.9	156.2	21.8	163.7
	3.0 %	6.5	249.0	22.0	215.7	34.2	257.3
3 week	Control	3.0	100.0	6.1	100.0	18.8	100.0
	1.0 %	4.9	162.4	12.3	202.0	24.1	128.2
	2.0 %	5.6	183.2	17.4	285.5	27.2	144.4
	3.0 %	9.5	314.2	26.9	442.6	54.1	287.8

Table 2. Leaf growth coefficients (GC) and the relative index (RI) to the control plot of sample plants in each treatment. Sg: *S. gracilistyla*, Sk: *S. koreensis*, Sp: *Spiraea prunifolia* var. *simplicifolia*

Water supply interval	Terra cottem content	Sg		Sk		Sp	
		GC	RI	GC	RI	GC	RI
1 week	Control	39.2	100.0	55.4	100.0	11.0	100.0
	1.0 %	42.2	107.7	63.6	114.8	15.4	140.0
	2.0 %	47.3	120.7	72.5	130.9	20.0	181.8
	3.0 %	54.7	139.5	95.5	172.4	24.2	220.0
2 week	Control	52.3	100.0	25.9	100.0	12.7	100.0
	1.0 %	66.7	127.5	29.8	115.1	18.7	147.2
	2.0 %	74.0	141.5	40.9	157.9	25.2	198.4
	3.0 %	95.9	183.4	61.7	238.2	35.6	280.3
3 week	Control	17.8	100.0	13.5	100.0	9.08	100.0
	1.0 %	24.1	135.4	17.4	128.9	12.9	143.3
	2.0 %	28.3	159.0	21.2	157.0	16.5	184.4
	3.0 %	39.8	223.6	28.6	211.9	24.5	272.2

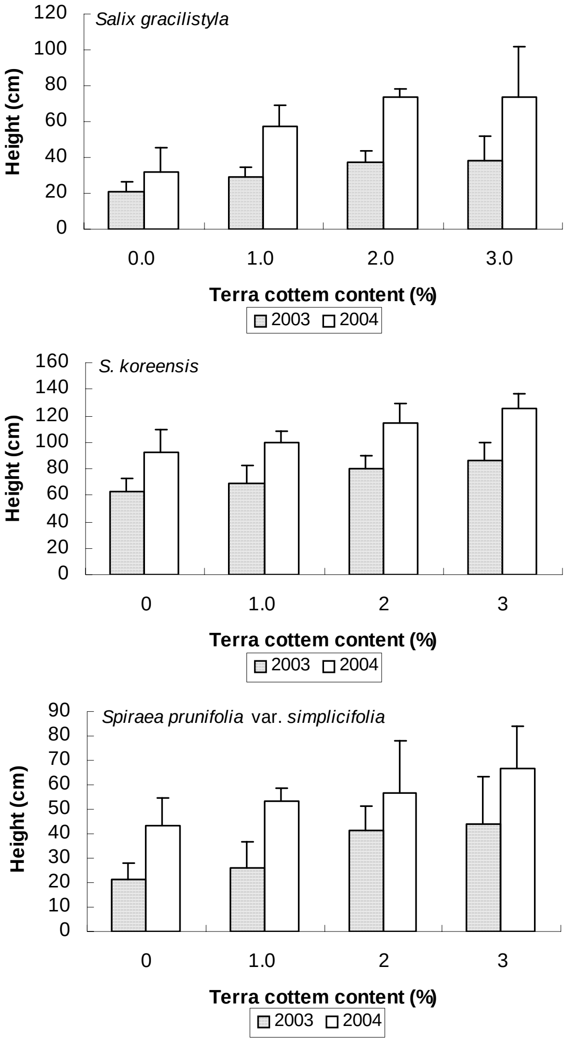

Fig. 2. A comparison of branch growth of sample plants in the field experimental plots with different Terra cottem contents.

Field experiment

The higher the TC contents, the larger the growth of sample plants was, and thereby showed the same trends as the results in the laboratory experiments (Fig. 2). Soil water contents also showed the same trends (Fig. 3). Furthermore, TC contents influenced the mortality of sample plants on the concrete block as well (Fig. 4).

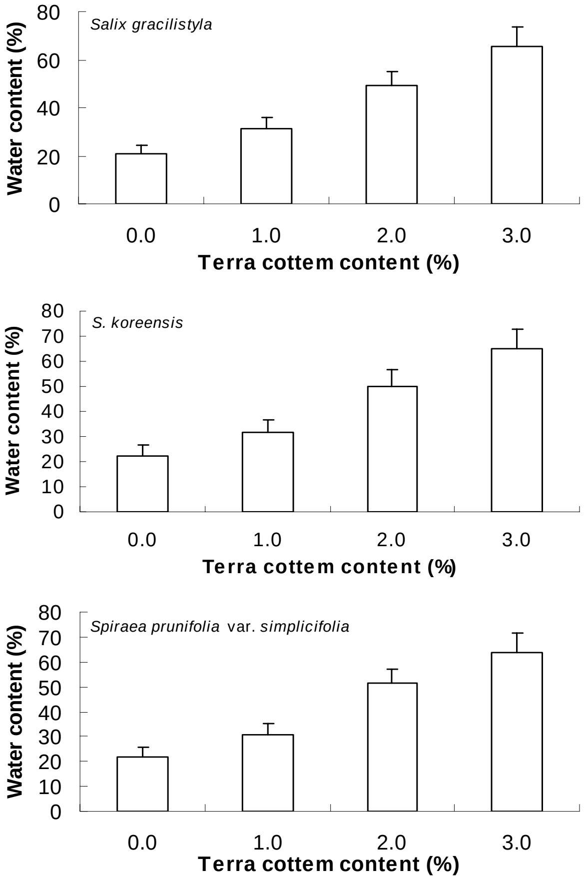

Fig. 3. Comparisons of soil water contents in field experimental plots with different Terra cottem contents and sample plants.

Restoration effects

Restored stands were isolated from stands released without any restoration treatment and thereby approached to the stands of control site in the result of stand ordination (Fig. 5). That is, species composition of the restored stands showed a change similar to that of control sites.

The multi-layer coverage of vegetation was obtained by accumulating coverage of all plant species that appeared in the quadrat. The index was higher in the restored plots compared with those released without any restoration treatment (Fig. 6). The result implies a possibility that vegetation can be introduced in a state that physical stability is ensured.

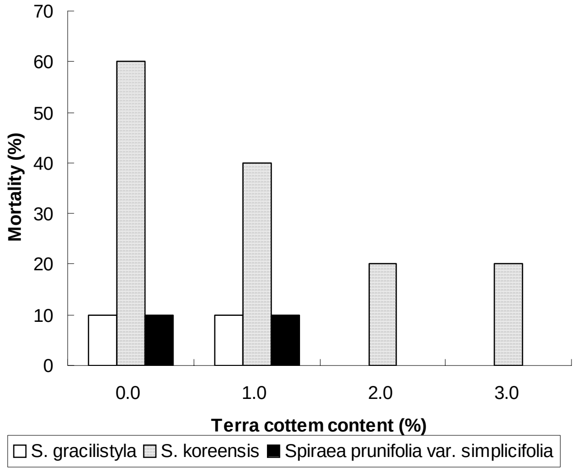

Fig. 4. A comparison of mortalities of sample plants among field experimental plots with different TC contents.

Rank-abundance curves showed that species richness was higher and slant was looser in the restored plot (Fig. 7). That is, species diversity was higher in the restored plot than in the left one without treatment.

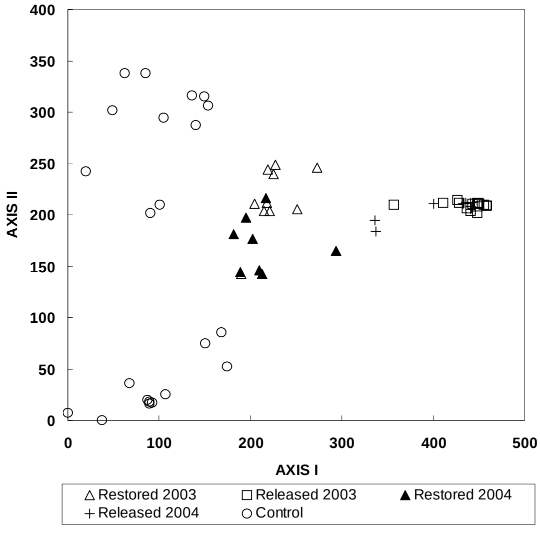

Fig. 5. Stand ordination of the restored, released without any treatment, and control sites.

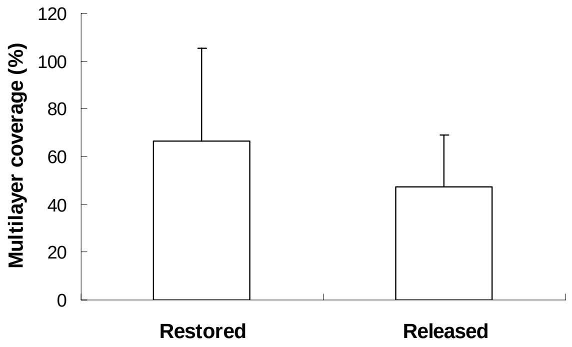

Fig. 6. A comparison of multi-layer coverage of vegetation between plots restored and released without any restoration treatment.

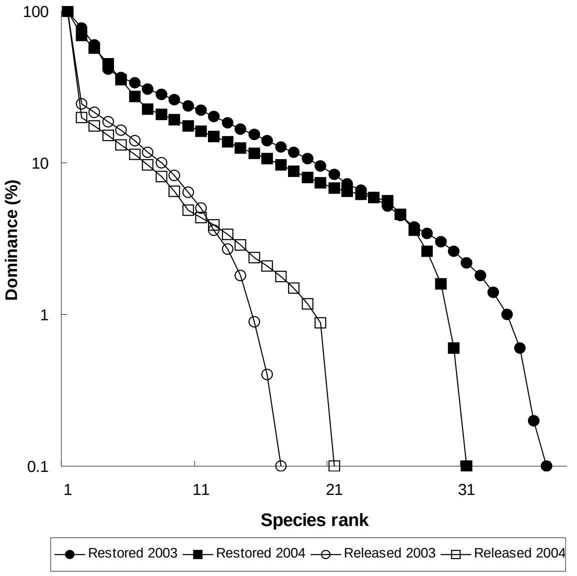

Fig. 7. A comparison of species rank-dominance curves between sites restored and released without any treatment. Numerals attached to legend indicate the year surveyed.

Discussion

TC used to ameliorate the planting bed on the concrete wall contributed to increase the survival and growth rates of sample plants by improving water holding capacity. It could be evaluated that these environmental amelioration and beneficial effects for plant survival and growth obtained by applying a substrate ameliorator provided a starting point to lead successfully this long lasting restoration project. Ecological restoration aims to recover the sound natural state prior to artificial destruction (Aronson et al. 1993, SER 2002). Species composition similar to that of the control sites, and higher diversity and vegetation coverage in the restored sites compared with the released ones without any restoration treatment, reflected such a restoration effect. Another goal of restoration is to ensure the pleasant living environment by buffering function of the nature recovered through restoration process (Freedman 1995, Gunn 1995). Such buffering function of vegetation can be displayed in a maximum in the complete state equipped with the integrate structure and function, that is to say, the natural system (International Ecology Center 1995, Lee and You 2001). It is expected that vegetation of the restored sites, which holds more diverse species composition, can display better effect in this respect.

Furthermore, species diversity is an important factor, which determines stability of a system (Magurran 1988). Ecological restoration intends to transform a simple and instable system due to human disturbance into a complex and stable system (Bradshaw 1984). Therefore, it can be evaluated that higher species diversity in the restored sites compared with the left ones without any treatment displayed restoration effect in this respect as well.

Conclusion

TC used as a soil ameliorator in this study increased water holding capacity. Moreover, it increased survival rate of sample plants and also contributed to facilitate their growth. These environmental amelioration and beneficial effects for plant survival and growth would contribute to increase the effects of restoration by playing a role of trigger factor. Higher vegetation coverage and species diversity, and more similar species composition to that of the control site confirmed in the restored sites reflect the trends. Furthermore, these results implied a possibility that a restoration improving naturalness can be realized by introducing vegetation in a state maintaining the physical stability relied on artificial facilities.

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