Int. J. of GEOMATE, June, 2014, Vol. 6, No. 2 (Sl. No. 12), pp. 885-891
Geotech., Const. Mat. & Env., ISSN:2186-2982(P), 2186-2990(O), Japan

THE RELATION BETWEEN ROAD CRACK VEGETATION AND PLANT BIODIVERSITY IN URBAN LANDSCAPE

Taizo Uchida[1], JunHuan Xue[1,2], Daisuke Hayasaka[3], Teruo Arase[4], William T. Haller[5] and Lyn A. Gettys[5]

[1]Faculty of Engineering, Kyushu Sangyo University, Japan; [2]Suzhou Polytechnic Institute of Agriculture, China; [3]Faculty of Agriculture, Kinki University, Japan; [4]Faculty of Agriculture, Shinshu University, Japan; [5]Center for Aquatic and Invasive Plants, University of Florida, USA

ABSTRACT: The objective of this study is to collect basic information on vegetation in road crack, especially in curbside crack of road, for evaluating plant biodiversity in urban landscape. A curbside crack in this study was defined as a linear space (under 20 mm in width) between the asphalt pavement and curbstone. The species composition of plants invading curbside cracks was surveyed in 38 plots along the serial National Route, over a total length of 36.5 km, in Fukuoka City in southern Japan. In total, 113 species including native plants (83 species, 73.5%), perennial herbs (57 species, 50.4%) and woody plants (13 species, 11.5%) were recorded in curbside cracks. Buried seeds were also obtained from soil in curbside cracks, which means the cracks would possess a potential as seed bank. Incidentally, no significant differences were found in the vegetation characteristics of curbside cracks among land-use types (Kolmogorov-Smirnov Test, $P > 0.05$). From these results, curbside cracks would be likely to play an important role in offering habitat for plants in urban area.

Keywords: Biodiversity, Road Crack, Seed Bank, Urban Area, Vegetation

1. INTRODUCTION

Roads are important infrastructure components that provide critical corridors for transporting goods and humans. Expansion and integration of asphalted road networks would symbolize urbanization. Some plants, however, become established in curbside cracks of road and cause deterioration of asphalt and curbs, reducing road surface longevity and safety (Fig. 1). Therefore, road managers spend a considerable amount of time and money on roadside vegetation management [4]. In this context, several ecological traits of plants in curbside cracks of road have been also shown for effective road management [4], [5], [18].

On the other hand, there has been growing interest in the effect of urbanization on the biodiversity and ecosystems [12], [19], [20]. And, to evaluate the urban biodiversity and ecosystems, the sites where could be habitats for plant, such as wetland, riverside, garden, park or shrine in the cities, have been surveying [12].

Fig. 1 Some plants established in curbside cracks of road.

In this study, we hypothesize that road cracks, especially curbside cracks of road, can be site where some plants establish including ecologically valuable species, and be evaluated as useful habitat for plant. To investigate above hypothesis, we surveyed plant that invades curbside cracks of road; we compared species composition and characteristics in the curbside cracks among land-use types in urban area. The objective of this study is to collect basic information on vegetation in road crack, especially in curbside cracks of road, for evaluating plant biodiversity in urban area.

2. MATERIALS AND METHODS

2.1 Study Area

Surveying of vegetation in curbside cracks was conducted in Fukuoka City, southern Japan, in September 2012 along National Route 3, 202 and 263, over a total distance of 36.5 km (Fig. 2).

Fukuoka City is one of the biggest cities in Japan besides Tokyo, Osaka and Nagoya, and the population is around one and a half million, the density is 4,392 km^{-2}, as of May 1, 2013 (Fukuoka City Environmental Data System). According to AMEDAS (Automated Meteorological Data Acquisition System) from 2003 to 2012, Fukuoka

City lies in the warm-temperature zone, with values of Kira's Warmth Index [9] ranging from 143.4 to 155.5 °C and with annual precipitation of 1,020 to 2,018 mm.

2.2 Species Composition and Characteristics

The species composition of vegetation in curbside cracks was recorded according to the methodology of Braun-Blanquet cover-abundance scale [2]. A curbside crack was defined as a linear space (under 20 mm in width) between the asphalt pavement and curbstone [4]. We located 38 survey plots along the route at intervals of approximately 1 km. The size of the plots was 50 m (length) × 20 mm (maximum width of the crack).

Plant nomenclature used in this paper followed Miyawaki et al. (1994), Baba (1999) and Shimizu (2003). All the recorded species were categorized by life form (dormancy form, disseminule form, radicoid form and growth form) and invasive status (native or non-native), in order to characterize the vegetation surveyed. Life form was based on the description by Raunkiaer (1934) and Numata (1990), and we distinguished non-native from native species based on published literature [1], [11], [17]. Using aerial photographs and field observation, dominant land-use types within a radius of 100 m from each survey plot were classified as forest, business area, residential districts, developed land, dry fields and paddy fields.

2.3 Soil Property

The soil was collected from curbside crack in each survey plot, using stainless spatula, for measurement of pH and EC.

And then, in order to estimate the potential vegetation in curbside crack, the soil obtained from the crack was spread over 20 cm^2 with thickness of 1.5 cm on the vinyl pot filled with expanded vermiculite. Prepared pots were put under the constant temperature of 25 °C with 12 hours light of 3,300-3,600 lux a day for 3 months, and plant emerged from the soil was regularly identified.

2.4 Data Analysis

Braun-Blanquet cover-abundance scale (r, +, I, II, III, IV and V) was transformed as follows: r and +, 0.1%; I, 5.0%; II, 17.5%; III, 37.5%; IV, 62.5% and V, 87.5%.

To test whether characteristics of vegetation in curbside cracks were different among land-use types, we conducted a Kolmogorov-Smirnov test, under the null hypothesis that vegetation characteristics of curbside cracks were equivalent across land-use types [3], [21]. The vegetation characteristics employed were the following: the total number of species, average number of species, Sannon-Wiener's diversity index (*H*') and the percentage of non-native species.

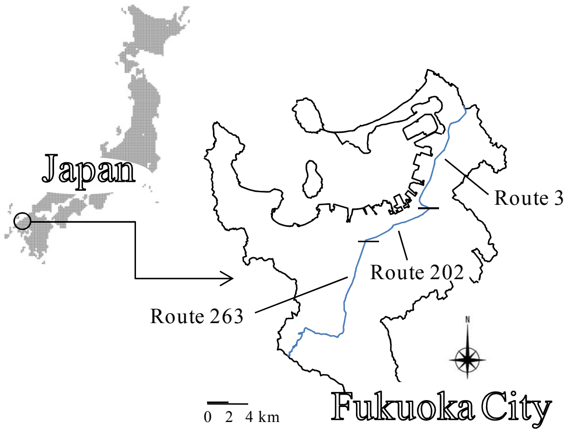

Fig. 2 Location of study sites.

Horn's measurement of overlap [6] was done with mean cover data of species in each land-use type in order to examine the similarity of species composition among land-use types. According to the Eq. (1), Summed Dominance Ratio (SDR) of species [14] in each land-use type was also calculated;

$$SDR = (F' + C') / 2 \quad (1)$$

Where *F*' and *C*' is the ratio of frequency and cover of each species to the numbers of the most abundant species, respectively.

To find out whether the proportion of each life form was different among land-use types, we conducted a two-way ANOVA. The differences in pH and EC of curbside crack soil among land-use types were also analyzed using an ANOVA. All of the data for the ANOVAs were used after transforming to ln(x + 0.5) value.

3. RESULTS

3.1 Species Composition and Characteristics

In total, 113 species including 83 (73.5%) natives were observed in curbside cracks along the surveyed routes (Appendix 1), of which 100 (88.5%) species were herbaceous and 13 (11.5%) species were woody plants. In the former, 57 perennials (50.4%) were recorded. Of the 36 families obtained in this survey (Appendix 1), Poaceae and Asteraceae

Table 1 Vegetation characteristics of curbside cracks among land-use types.

Land-use types	Vegetation characteristics				
	Number of survey plots	Total number of species	Average number of species	Sannon-Wiener's diversity index (H')	Percentage of non-native species
Forest	8	63	13.3	1.670	19.0
Business area	12	45	10.6	1.952	35.6
Residential districts	14	41	8.7	1.785	39.0
Developed land	1	20	20.0	2.987	40.0
Dry fields	3	23	10.0	1.675	30.4
Paddy fields	0	-	-	-	-
P-value	-	0.200^{ns}	0.194^{ns}	0.053^{ns}	0.200^{ns}

$P > 0.05$: ns indicates not significant using Kolmogorov-Smirnov test.

accounted for the majority of herbaceous plants (47/100 species), and Ulmaceae was dominant in woody plants recorded (4/13 species).

No significant differences were found in the vegetation characteristics of curbside cracks across land-use types ($P > 0.05$) (Table 1).

Using Horn's measurement of overlap three vegetation types could be distinguished (Fig. 3). Type V1 contained business area and residential districts (n = 26), and Type V2 included forest and developed land (n = 9). Type V3 consisted of dry fields (n = 3). Common species to all vegetation types (12/113 species) were *Artemisia princeps*

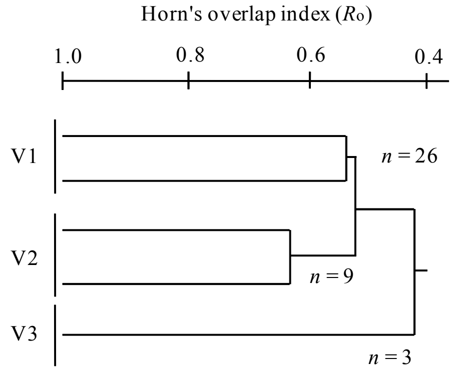

Fig. 3 Classification of 5 land-use types based on mean cover of component species. See Appendix 1.

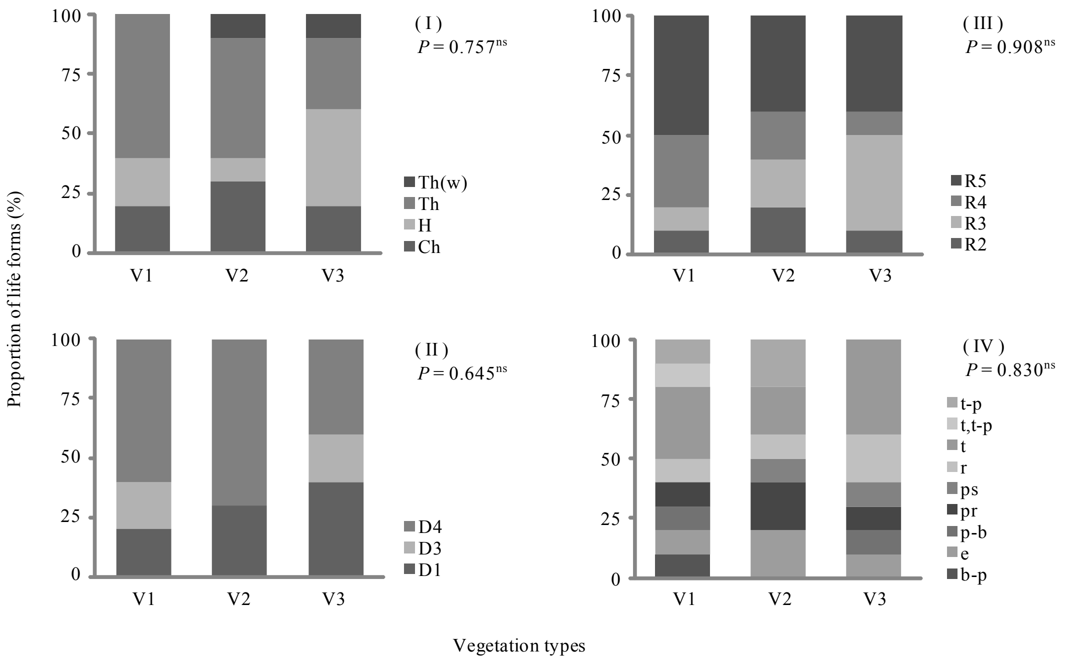

Fig. 4 Proportion of life forms of the top 10 species in SDR in each vegetation type. Life forms are as follows: (I), dormancy form; (II), disseminule form; (III), radicoid form and (IV), growth form. $P > 0.05$: ns indicates not significant using a two-way ANOVA. See Fig. 3.

Pamp., *Digitaria ciliaris* (Retz.) Koel., *Eleusine indica* (L.) Gaertn., *Euphorbia supina* Rafin., *Lactuca indica* L., *Oxalis corniculata* L., *Paspalum dilatetum* Poir., *Sagina japonica* (Sw.) Ohwi, *Setaria viridis* (L.) Beauv., *Solidago altissima* L., *Taraxacum officinale* Weber and *Youngia japonica* (L.) DC. (Appendix 1). On the other hand, species that emerged just in some specific type or other were also observed. The species occurred only in Type V1 were 35 plants, e.g. *Cynodon dactylon* (L.) Pers., *Gnaphalium japonicum* Thunb. and *Trifolium dubium* Sibth., and those in Type V2 were 39 plants including *Bidens frondosa* L., *Carex lenta* D. Don, *Clinopodium micranthum* (Regel) Hara, *Festuca arundinacea* Schreb., *etc*. Four species of *Euphorbia muculata* L., *Lespedeza cuneata* (Dum. Cours.) G. Don, *Ulmus davidiana* Planch. var. *japonica* (Rehder) Nakai and *Viola mandshurica* W. Becker were found only in Type V3.

In the top 10 species of SDR in each type (Fig. 4), lots of perennials (H and Ch) were found as well as ephemeral plants (Th(w) and Th), and barochory (D4) or anemochory (D1) was the dominant dispersal modes. Definite tendency was not shown in radicoid and growth forms. Incidentally, the proportion of life forms of vegetation in curbside cracks was not statistically different among the types ($P > 0.05$).

3.2 Soil Property

There was no significant difference in pH and EC of curbside crack soil across the types ($P > 0.05$) (Appendix 1).

Seedlings from curbside crack soil spread over the pot were shown in every pot (max., 8 species and min., 1 species) (Table 2 and Appendix 1). In total, 20 species emerged from the pot, of which 2 species had not been observed at the field survey.

4. DISCUSSION

Investigating the vegetation in curbside cracks of road, 36 families with 113 species were observed (Appendix 1). Our results are not surprising because road has also become an important corridor for dispersal and expansion of plants as well as transporting humans and all the goods we need [8], [10].

Ephemeral (annual and biennial) and non-native plants are species having the highest advantages in curbside cracks [5]. Of the 113 species recorded in this survey (Fig. 4 and Appendix 1), however, plenty of perennial (61.9%), native (73.5%) and woody (11.5%) species were confirmed. The characteristics including diversity index (*H*') were not also affected by land-use types (Table 1). Furthermore, 20 species including 2 species not recorded at the field survey were obtained from the soil in curbside cracks of road (Table 2 and Appendix 1). Therefore, we suggest that curbside cracks would be likely to play an important role in offering habitat and seed bank for plants regardless of surrounding land-use types in urban landscape although there is the problem of deteriorations of road [4], [5].

Hayasaka et al. (2011, 2012) mentioned that the main ecological types of curbside crack vegetation were species with gravity dispersal (barochory) or wind dispersal (anemochory) mechanisms. Suto et al. (2006) had the same opinion too. Additionally, both of them also reported that Poaceae and Asteraceae were dominant families in curbside crack environments [4], [5], [18]. These previous studies support our results that species with barochory or anemochory mechanisms and those in Poaceae and Asteraceae dominated the plants observed in this survey (Fig. 4 and Appendix 1). Incidentally, correlation between these dispersal modes and families would be definite.

A common species among vegetation types could be defined as a typical species in curbside crack vegetation (Fig. 3 and Appendix 1); to name a few,

Table 2 Number of species emerged from soil of curbside crack obtained in each vegetation type.

Vegetation types	Study parameter				
	Number of survey plots	Total number of species	Average number of species	Maximum number of species	Minimum number of species
V1	26	17	3.4	7	1
V2	9	14	3.1	6	1
V3	3	10	4.3	8	1
Total	38	20	3.4	8	1

See Fig. 3 and Appendix 1. Eight unknown species were excluded. Of the 20 species identified, 2 plants, *Juncus tenuis* Willden. and *Aira caryohyllea* L., had not been recorded at the field survey.

Artemisia princeps Pamp., *Digitaria ciliaris* (Retz.) Koel., *Taraxacum officinale* Weber, *etc.* Conversely, a unique species in each vegetation type would be a peculiar species which is affected by the surrounding land-use, e.g. *Phyllanthus urinaria* L., *Talinum crassifolium* Willd., *Impatiens textori* Miq. and *Viola mandshurica* W. Becker. To obtain bio-diversity more from curbside cracks of road in urban landscape, therefore, securing various land-use types in the city would be also needed.

Recognizing road is one of the serious problems today in natural ecosystems would be required- for instance, expansion and integration of road networks, which accompany urbanization, can cause fragmentation and extinction of plant populations and communities [7], [16]. And furthermore, roads become dispersal corridors for plants, including non-native species [8], [10]. However, to appreciate the role of curbside cracks of road in offering habitat and seed bank place for plants, including much native species, might be also very important in urban biodiversity.

5. ACKNOWLEDGEMENTS

This research was partially supported by Fukuoka Prefecture. We sincerely thank A. Tanaka, M. Furuno, F. Oda, S. Nakanishi, H. Matsugi and H. Yonao, Environ. Sci. Appl. Ecol. Laboratory, Kyushu Sangyo University, for their assistance with the field work.

Appendix 1 Species recorded in this survey and they were listed, according as component species in each vegetation type.

Species	Family	Common name	Vegetation types V1 (*n* = 26)	V2 (*n* = 9)	V3 (*n* = 3)	Occurrence frequency (%)
Artemisia princeps Pamp. #	Asteraceae	Japanese mugwort	Ⅱ	Ⅴ	Ⅴ	81.6
Digitaria ciliaris (Retz.) Koel. † #	Poaceae	Southern crabgrass	Ⅲ	Ⅱ	Ⅰ	84.2
Eleusine indica (L.) Gaertn. †	Poaceae	Indian goosegrass	Ⅲ	Ⅱ	Ⅱ	47.4
Euphorbia supina Rafin. * †	Euphorbiaceae	Milk purslane	Ⅲ	Ⅰ	Ⅰ	55.3
Lactuca indica L. † #	Asteraceae	Indian lettuce	Ⅱ	Ⅱ	Ⅱ	36.8
Oxalis corniculata L. #	Oxalidaceae	Sorrel	Ⅲ	Ⅱ	Ⅲ	63.2
Paspalum dilatatum Poir. *	Poaceae	Dallis grass	+	+	Ⅰ	7.9
Sagina japonica (Sw.) Ohwi † #	Caryophyllaceae	Pearlwort	+	+	Ⅰ	10.5
Setaria viridis (L.) Beauv. † #	Poaceae	Green bristlegrass	Ⅴ	Ⅱ	Ⅱ	76.3
Solidago altissima L. *	Asteraceae	Canada goldenrod	Ⅰ	Ⅳ	Ⅰ	23.7
Taraxacum officinale Weber *	Asteraceae	Dandelion	Ⅲ	Ⅲ	Ⅲ	78.9
Youngia japonica (L.) DC. †	Asteraceae	Oriental false hawksbeard	r	+	Ⅱ	13.2
Amaranthus spinosus L. * †	Amaranthaceae	Spiny amaranth	r			2.6
Ambrina ambrosioides (L.) Spach * †	Chenopodiaceae	Mexican tea	r			2.6
Ambrosia artemisiaefolia L. var. *elatior* (L.) Descurtilz * †	Asteraceae	Ragweed	r			2.6
A virginicus L. *	Poaceae	Broomsadge bluestem	r			2.6
Aphananthe aspera (Thunb.) Planch.	Ulmaceae	Aphananthe	Ⅱ			5.3
Calystegia hederacea Wall.	Convolvulaceae	Japanese false bindweed	r			2.6
Capsella bursa-pastoris Medicus † #	Brassicaceae	Shepherd's purse	r			2.6
Cayratia japonica (Thund.) Gagn.	Vitaceae	Bushkiller	r			2.6
Celtis sinensis Pers. var. *japonica* (Planch.) Nakai	Ulmaceae	Chinese hackberry	+			2.6
Cynodon dactylon (L.) Pers.	Poaceae	Bermuda grass	Ⅲ			23.7
Cyperus iria L. †	Cyperaceae	Rice galingale	r			5.3
Cyperus rotundus L.	Cyperaceae	Nut grass	r			2.6
Digitaria violascens Link †	Poaceae	Violet crabgrass	Ⅰ			5.3
Eragrostis multicaulis Steud. †	Poaceae	------	r			2.6
Stenactis annuus (L.) Cass. * †	Asteraceae	Annual fleabane	Ⅰ			18.4
Glechoma hederacea L.subsp.*grandis* (A.Gray) Hara #	Lamiaceae	Alehoof	r			2.6
Gnaphalium japonicum Thunb. #	Asteraceae	Japanese cudweed	Ⅰ			2.6
Isachne globosa (Thunb.) O. Kuntze	Poaceae	Dwarf white-striped banboo	r			2.6
Kalimeris yomena Kitam.	Asteraceae	------	r			2.6
Melia azedarach L. var. *subtripinnata* Miq.	Meliaceae	Chinaberry	+			2.6
Muhlenbergia japonica Steud.	Poaceae	------	+			2.6
Ophiopogon japonicus (L. fil.) Ker Gawl.	Liliaceae	Mondo grass	+			10.5
Panicum dichotomiflorum Michx. * †	Poaceae	Fall panicum	r			2.6
Phyllanthus urinaria L. † #	Pyllanthaceae	Chamberbitter	r			5.3
Phytolacca americana L. *	Phytolaccaceae	Pokeweed	r			2.6
Polygonum lapathifolia (L.) S. F. Gary †	Polygonaceae	Curlytop knotweed	r			2.6
Portulaca oleracea Cvs. * †	Portulacaceae	Purslane pusley	r			2.6
Portulaca oleracea L. †	Portulacaceae	Common purslane	+			7.9
Rorippa indica (L.) Hiern †	Cruciferae	Variableleaf yellowcress	+			2.6
Sedum bulbiferum Makino †	Crassulaceae	------	r			2.6
Talinum crassifolium Willd. * #	Portulacaceae	Coral flower	r			5.3
Trifolium dubium Sibth. * † #	Fabaceae	Suckling clover	r			2.6
Zanthoxylum schinifolium Sieb. et Zucc.	Rutaceae	------	r			2.6
Zephyranthes candida (Lindl.) Herbert *	Amaryllidaceae	Fairy lily	r			2.6
Zoysia japonica Steud.	Poaceae	Lawnglass	Ⅱ			18.4
Acalypha australis L. † #	Euphorbiaceae	Australian acalypha		+		2.6
Achyranthes bidentata Blume var. *Tomentosa* (Honda) Hara	Amaranthaceae	------		+		2.6
Amorpha fruitcosa L. *	Fabaceae	Desert false indigo		+		2.6
forma citrulloides (Lebas) Rehd.	Vitaceae	------		+		2.6
Aster ageratoides Turcz. subsp.	Asteraceae	Wild chrysanthemum		+		2.6
Kalimeris incisa (fisch) DC.	Asteraceae	------		Ⅰ		5.3

Appendix 1 Continued.

Species	Family	Common name	Vegetation types V1 (*n* = 26)	V2 (*n* = 9)	V3 (*n* = 3)	Occurrence frequency (%)
Bidens frondosa L. * †	Asteraceae	Devil's beggartick		+		2.6
Urtica thunbergiana Sieb. et Zucc.	Urticaceae	Ramie		II		10.5
Boehmeria tricuspis (Hance) Makino	Urticaceae	------		+		2.6
Boehmeria spicata (Thunb.) Thunb.	Urticaceae	------		+		2.6
Boenninghausenia japonica Nakai	Rutaceae	------		+		2.6
Carex lenta D. Don	Cyperaceae	Flat sedge		+		2.6
Chenopodium centrorubrum (Makino) Nakai † #	Chenopodiaceae	Fat hen		+		2.6
Cirsium dipsacolepis (Maxim.) Matsum.	Asteraceae	------		+		2.6
Clerodendron trichotomum Thunb.	Verbenaceae	Harlequin glory bower		+		2.6
Clinopodium micranthum (Regel) Hara	Lamiaceae	------		+		2.6
Dactyloctenium aegyptium (L.) Beauv. *	Poaceae	Crowfoot grass		+		2.6
Dioscorea japonica Thunb.	Dioscoreaceae	Japanese yam		+		2.6
Duchesnea indica (Andr.) Focke	Rosaceae	Mock strawberry		+		2.6
Echinochloa crus-galli (L.) Beauv. var. *caudata* (Roshev.) Kitag. † #	Poaceae	Barnyardgrass		+		2.6
Festuca arundinacea Schreb. *	Poaceae	Tall fescue		+		2.6
Ficus erecta Thunb.	Moraceae	------		+		2.6
Geranium nepalense Sweet subsp. *Thunbergii* (Sieb. et Zucc) Hara	Geraniaceae	Oriental geranium		I		5.3
Impatiens textori Miq. †	Balsaminaceae	Touch-me-not		+		2.6
Justicia procumbens L. †	Acanthaceae	Common asystasia		II		10.5
Oplismenus undulatifolius (Arduino) Roemer et Schultes	Poaceae	Wavyleaf basketgrass		+		2.6
Oplismenus compositus (L.) Beauv.	Poaceae	------		+		2.6
Paspalum thunbergii Kunth	Poaceae	Japanese paspalum		+		2.6
Petasites japonicus (Sieb. et Zucc.) Maxim.	Asteraceae	Fuki		+		2.6
Picris hieracioides L. subsp. *japonica* (Thunb.) Krylov †	Asteraceae	Hawkweed oxtongue		+		2.6
Plantago lanceolata L. *	Plantaginaceae	Ribwort plantain		+		2.6
Polygonum caespitosum Bl. var. *laxiflorum* Meisn. †	Polygonaceae	Asiatic smartweed		I		5.3
Reynoutria japonica Houtt.	Polygonaceae	Japanese knotweed		+		2.6
Persicaria Longiseta (De Bruyn) Kitag. †	Polygonaceae	Tufted knotweed		I		5.3
Persicaria thunbergii (Sieb. et Zucc.) H. Gross † #	Polygonaceae	Water pepper		+		2.6
Rubus buergeri Miq.	Rosaceae	------		+		2.6
Rumex japonicus Houtt.	Polygonaceae	------		I		5.3
Trifolium repens L.	Leguminosae	White clover		+		2.6
Viola verecunda A. Gray	Violaceae	Japanese violet		I		5.3
Euphorbia muculata L. * †	Euphorbiaceae	Eyebane			I	2.6
Lespedeza cuneata (Dum. Cours.) G. Don	Fabaceae	Sericea lespedeza			I	2.6
Ulmus davidiana Planch. var. *japonica* (Rehder) Nakai	Ulmaceae	Japanese elm			I	2.6
Viola mandshurica W. Becker	Violaceae	Violet			II	2.6
Artemisia capillaris Thunb.	Asteraceae	Capillary artemisia	+	+		5.3
Conyza bonariensis (L.) Cronq. * †	Asteraceae	Flax-leaf fleabane	II	+		23.7
Cyperus microiria Steud. † #	Cyperaceae	Asian flatsedge	+	I		10.5
Dactylis glomerata L. *	Poaceae	Orchard grass	r	+		5.3
Digitaria timorensis (Kunth) Balansa †	Poaceae	------	II	II		26.3
Eragrostis poaeoides Beauv. * †	Poaceae	------	III	II		21.1
Gnaphalium spicatum Lam. *	Asteraceae	Spiked cudweed	r	I		7.9
Leptochloa chinensis (L.) Nees †	Poaceae	Asian sprangletop	r	+		5.3
Paspalm urvillei Steud. *	Poaceae	Knot grass	+	+		10.5
Persicaria capitata (Buch. -Ham. ex D. Don) H. Gross * #	Polygonaceae	Pink-head knotweed	r	+		5.3
Plantago asiatica L.	Plantaginaceae	Chinese plantain	+	II		15.8
Oenothera Laciniata Hill * †	Onagraceae	Cutleaf eveningprimrose	I	III		10.5
Sambucus chinensis Lindley	Caprifoliaceae	Chinese elderberry	r	I		7.9
Setaria glauca (L.) Beauv. †	Poaceae	Yellow foxtail	I	II		13.2
Solanum nigrum L. †	Solanaceae	Black nightshade	r	I		7.9
Zelkova serrata (Thunb.) Makino	Ulmaceae	Japanese zelkova	r	+		5.3
Cleistogenes hackelii (Honda) Honda	Poaceae	------	I		I	13.2
Erigeron canadensis L. * †	Asteraceae	Canadian horseweed	I		I	13.2
Oxalis corymbosa DC. *	Oxalidaceae	Violet wood-sorrel	+		I	10.5
Zanthoxylum ailanthoides Sieb. et Zucc.	Rutaceae	Japanese prickly-ash	+		I	5.3
Eragrostis ferruginea (Thund.) Beauv.	Poaceae	Korean lovegrass		+	I	5.3
Miscanthus sinensis Anderss.	Poaceae	Eulalia		I	II	7.9
Sporobolus fertilis (Steud.) W. Clayton	Poaceae	Giant paramatta grass		+	IV	5.3
pH of soil in curbside cracks; mean ± S.D.	P = 0.053^{ns}		7.5 ± 0.4	7.2 ± 0.6	7.2 ± 0.4	
EC (μS cm^{-1}) of soil in curbside cracks; mean ± S.D.	P = 0.924^{ns}		162.1 ± 53.6	157.3 ± 65.0	173.0 ± 22.3	

Roman numerals and other symbols for each species indicate SDR classes, defined as follows: r, under 5%; +, under 10%; I, under 20%; II, under 40%; III, under 60%; IV, under 80% and V, above 80%. $P > 0.05$: ns indicates not significant using an ANOVA. *, non-native species; †, ephemeral species (annual and biennial plants) and #, species emerged from soil [See Table 2]. Highlight: woody species. ------: unknown.

6. REFERENCES

[1] Baba, T., 1999. Identifying woody species by their leaf appearances. Shinano Mainichi Shinbunsha, Nagano. 396 pp. *In Japanese.*

[2] Braun-Blanquet, J., 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde, 3rd ed. Springer-Verlag, Vienna. 865 pp.

[3] Davis, J.C., 1986. Statistics and data analysis in geology, 2nd ed. John Wiley & Sons, New York. 656 pp.

[4] Hayasaka, D., Asasaka, M., Miyauchi, D. and Uchida, T., 2011. Classification of roadside weeds along two highways in different climatic

zones according to ecomorphological traits. Weed Technol. 25, 411-421.
[5] Hayasaka, D., Asasaka, M., Miyauchi, D., Elgene, O.B. and Uchida, T., 2012. Qualitative variation in roadside weed vegetation along an urban–rural road gradient. Flora 207, 126-132.
[6] Horn, H.S., 1966. Measurement of "Overlap" in comparative ecological studies. Am. Nat. 100, 419-424
[7] Jantunen, J., Saarinen, K., Valtonen, A. and Saarnio, S., 2006. Grassland vegetation along roads differing in size and traffic density. Ann. Bot. Fenn. 43, 107-117.
[8] Kalwij, J.M., Milton, S.J. and McGeoch, M.A., 2008. Road verge as invasion corridors? A spatial hierarchical test in an arid ecosystem. Landscape Ecol. 23, 439-451.
[9] Kira, T., 1977. A climatological interpretation of Japanese vegetation zones. In: Miyawaki, A. and Tüxen, R. (Eds.), Vegetation science and environmental protection. Maruzen Co., Ltd., Tokyo. pp. 21-30
[10] Kowarik, I., 2003. Human agency in biological invasions: secondary releases foster naturalisation and population expansion of alien plant species. Biol. Invasions 5, 293-312.
[11] Miyawaki, A., Okuda, S. and Fujiwra, R., 1994. Handbook of Japanese vegetation. Shibundo Co., Ltd., Tokyo. 646 pp. *In Japanese.*
[12] Niemelä, J., 2011. Urban ecology. Oxford University Press Inc., New York. 374 pp.
[13] Numata, M., 1990. The ecological encyclopedia of wild plants in Japan. Zenkoku Noson Kyoiku Kyokai, Tokyo. 664 pp. *In Japanese.*
[14] Numata, M. and Yoda, K., 1957. The community structure and succession of artificial grasslands (1). J. Jap. Soc. Herb. Crops Grassl. Farm. 3, 4-11. *In Japanese.*
[15] Raunkiaer, C., 1934. Life forms of plants and plant geography. Oxford University Press, London. 632 pp.
[16] Rentch, J.S., Fortney, R.H., Stephenson, S.L., Adams, H.S., Grafton, W.N. and Anderson, J.T., 2005. Vegetation-site relationships of roadside plant communities in West Virginia, USA. J. Appl. Ecol. 42, 129-138.
[17] Shimizu, T., 2003. Naturalized plants of Japan. Heibonsha Ltd., Publishers, Tokyo. 337 pp. *In Japanese.*
[18] Suto, Y., Takahashi, Y. and Ogasawara, M., 2006. Summer weed vegetation of road pavement seams in Route 4. J. Weed Sci. Tech. 51, 1-9. *In Japanese.*
[19] Tiébré, M.-S., Saad, L. and Mahy, G., 2008. Landscape dynamics and habitat selection by the alien invasive *Fallopia* (Polygonaceae) in Belgium. Biodivers. Conserv. 17, 2357-2370.
[20] Tyser, R.W. and Worley, C.A., 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (USA). Conserv. Biol. 6, 253-262.
[21] Zar, J.H., 1984. Biostatistical analysis, 2nd ed. Prentice Hall, Englewood Cliffs. 718 pp.

Int. J. of GEOMATE, June, 2014, Vol. 6, No. 2 (Sl. No. 12), pp. 885-891.
MS No. 3177 received on June 14, 2013 and reviewed under GEOMATE publication policies.

Pertinent discussion including authors' closure, if any, will be published in the June. 2015 if the discussion is received by Dec. 2014.
Corresponding Author: Taizo Uchida