한국자연보호학회지, 제10권 제1호(2016)
Korean Journal of Nature Conservation
Vol. 10, No. 1, pp. 9-17
http://dx.doi.org/10.11624/KJNC.2016.10.1.009

PlantGPS: A Mobile Application for Collecting Biogeographical Information of Plants and for Their Monitoring

Jongsun Park[1], Yongsung Kim[1], Suhwan Nam[2], Kyeong-In Heo[1], Hong Xi[1], Suwang Jang[1], Suhyeon Park[3], and Sangtae Kim[3*]

[1]*InfoBoss Co. Ltd., Seoul 07766, Korea*
[2]*Chollipo Arboretum, Taean-gun 32121, Korea*
[3]*Department of Biology, Sungshin Women's University, Seoul 01133, Korea*

(Received 5 April 2016; Revised 17 May 2016; Accepted 7 June 2016)

PlantGPS: 식물 생물지리 정보 확보와 모니터링을 위한 모바일 어플리케이션

박종선[1] · 김용성[1] · 남수환[2] · 허경인[1] · 시 홍[1] · 장수왕[1] · 김상태[3*]

[1]인포보스 주식회사
[2]천리포수목원
[3]성신여자대학교 생물학과

(2016년 4월 5일 접수; 2016년 5월 17일 수정; 2016년 6월 7일 채택)

Abstract

Cost for plant survey has been dramatically reduced due to the development of mobile technology to obtain pictures with their GPS coordination. We developed a PlantGPS system consisting of an Android application specialized for collecting plant pictures and their locations using mobile devices, a server-side component for uploading data, and a web-based interface for managing and analyzing data. As examples of application of our PlantGPS system, surveys of “plants in Nangsae (Daksum) Island” and “ferns in Chollipo arboretum” were conducted. Results showed that our PlantGPS system could be used to quickly survey plant distribution in restricted area with reasonable time and effort.

Keywords: Andriod application, Biogeographical information, PlantGPS, Plant monitoring, Web interface

1. Introduction

Mobile devices including cellular phone and tablet PC have played a key role in changing our life styles in recent days. A variety of mobile activities such as checking email, browsing web sites, and developing programs can be easily conducted with mobile devices nowadays. Besides these mobile devices, Internet of Things (IoT) has been launched to connect everything, including electronics, cars, and various sensors (Kopetz, 2011). IoT promises dramatic change to our lives.

Almost every smart phone has sensors including a GPS (Geographical Positioning System) sensor to detect current location from satellite signals, light sensor for camera, gyroscope sensor, temperature sensor, and etc. With functions of mobile phone based on these sensors, we might be able to survey and monitor life in nature instantly, especially for plants. For example, if we visit a site where specific plants grow, we can collect their temporal and ecological characters by taking pictures as well as their location information by obtaining GPS data. Sensors of current mobile phones are accurate enough to get information for professional researchers.

Checking plant names and their locations in certain area is the first step to understand plants in nature. This has been conducted for a long time in various ways. With accumulated location data, we could understand the biological network of a certain area (Sturm, Racine *et al.*, 2001; Miller-Rushing *et al.*,

*Corresponding Author: Tel: +82-(0)2-920-7699
e-mail: amborella@sungshin.ac.kr

2006; Beckage *et al.*, 2008; Lenoir *et al.*, 2008; Han *et al.*, 2009; Park *et al.*, 2014). However, issues still remain because even experts could not survey all plants in a targeted area. One example is a report of unrecorded plants that are frequently reported even after the publication of a flora (e.g., Choi *et al.*, 2014; Park *et al.*, 2014). In addition, distribution of plants reported without voucher specimen or habitats currently available are controversial because later researchers could not confirm the existence of those recorded plant species.

To overcome these shortcomings for checking and monitoring plant species in a certain area, we developed a PlantGPS system consists of the following three parts: i) an Android application specialized for collecting plant pictures and their locations using mobile phone, ii) a server-side component for uploading data, and iii) a web interface for managing and analyzing data. With this system, ordinary people and parataxonomists can easily collect plant distribution data using their cellular phone on site. Later, professional taxonomists can confirm their plant identifications with the pictures and geographical locations without visiting the locations themselves. We can accumulate more plant distribution data if we distribute Android application to the public. Accumulated data may be used for studies of taxonomy, biogeography, conservation biology, and counterplan of climate changes in the future. As examples of using our system, we conducted the following two surveys: "plants in Nangsae Island (Daksum)" and "ferns in Chollipo arboretum". Our survey results showed that our PlantGPS system could be used to quickly survey plant distribution in restricted area with reasonable time and effort. It is also applicable for future monitoring.

2. Material and Methods

An Android software of PlantGPS system was developed under the environment of Eclipse with Android SDK. ANSI-C was used for developing server program as a server-side component. Web interface of the PlantGPS was constructed with the environment of Apache (http://www.apache.org/), PHP (http://www.php.net), and MySQL (http://www.mysql.com/).

Since 1976, plants have been transplanted in main areas of Chollipo arboretum and Nangsae Island (Daksum), a separate island apart from the main area of Chollipo arboretum. The island is closed to the public for restoration and monitoring the natural habitat. As tests of the PlantGPS system, we surveyed plants (both natural plants and transplanted plants) in Nangsae Island and ferns in the main area of Chollipo arboretum. Lab test of our application was performed using Galaxy Note 3~4, Galaxy S2~S6, and Galaxy Zoom 2 of Samsung Co. Intensive on-site test was

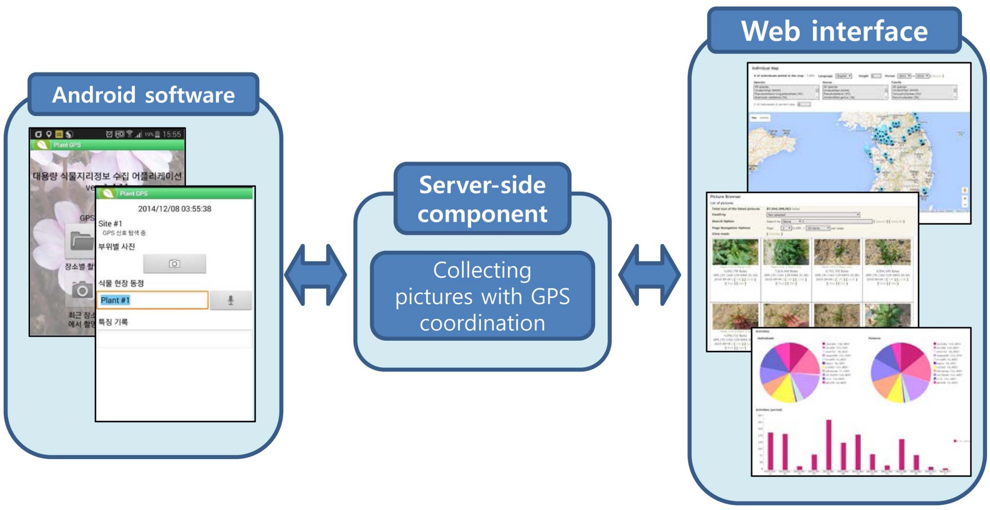

Figure 1. The three-tier structure of the PlantGPS system. Each transparent blue diagram indicates one-tier in the system. Double-sided arrow presents bidirectional data communication between two tiers.

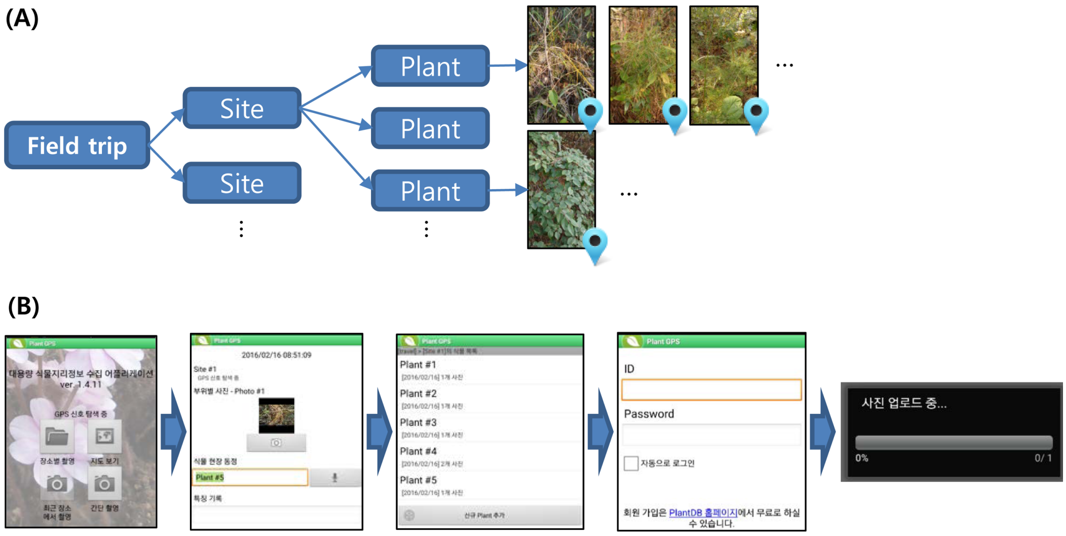

Figure 2. Data structure and Android interface of the PlantGPS System. (A) Data structure of the PlantGPS system consisting of field trips, sites, plants, and pictures. (B) The process from collecting data to uploading them to the server using Android application.

performed with Galaxy Zoom 2 for the two test surveys.

3. Results and Discussion

3.1. Structure of PlantGPS System

The PlantGPS system was developed with the following three components: i) an Android software for collecting plant pictures and its location (GPS coordination) by a mobile phone, ii) a server-side component receiving the collected data from Android software when users uploaded them, iii) a web interface (http://www.plantdb.info/) to manage and to analyze the collected data as well as to identify them (Figure 1). Android software can be installed on any mobile devices such as mobile phone, tablet PC, and digital camera with an operating system of Android. In this project, we used Samsung “Galaxy Zoom 2”, which provided much better image resolution (20M pixels) with better optical lens than normal mobile phone. The software can provide management function for “field trips”, “sites”, and “individual plants” that are important for classifying collected pictures during the data analysis step. Based on web interface, the PlantGPS can support a large-scale project involving multiple persons. With the aid of web interfaces, it also supports collaboration between field work people and people who are responsible for the identification and analyses under the PlantGPS system.

3.2. Data structure of the PlantGPS

Android software provides a simple interface for a field trip, site, and plant individuals with pictures and GPS coordination. A field trip can be defined based on individual plan. A field trip can contain several sites an individual plans to visit in a field trip. For example, if we have a plan to survey plants in Jiri Mountain in Korea, we can create a new field trip named “Jiri Mountain”. A site is defined as a specific area in a field trip. If we want to collect data from “Nogodan”, a specific area in Jiri Mountain, we can register “Nogodan” as a site under the field trip of “Jiri Mountain”. When a researcher finds a plant in a site, he/she can take a picture and record plant name with on-site brief identification and observed characters. Each picture has its own GPS coordination tracking back where the picture is taken for the plant (Figure 2A). For input plant names on site, we applied voice record system based on the database of common names for less typing on site. Taking multiple pictures for each individual is helpful for future researchers to re-identify plants more accurately later.

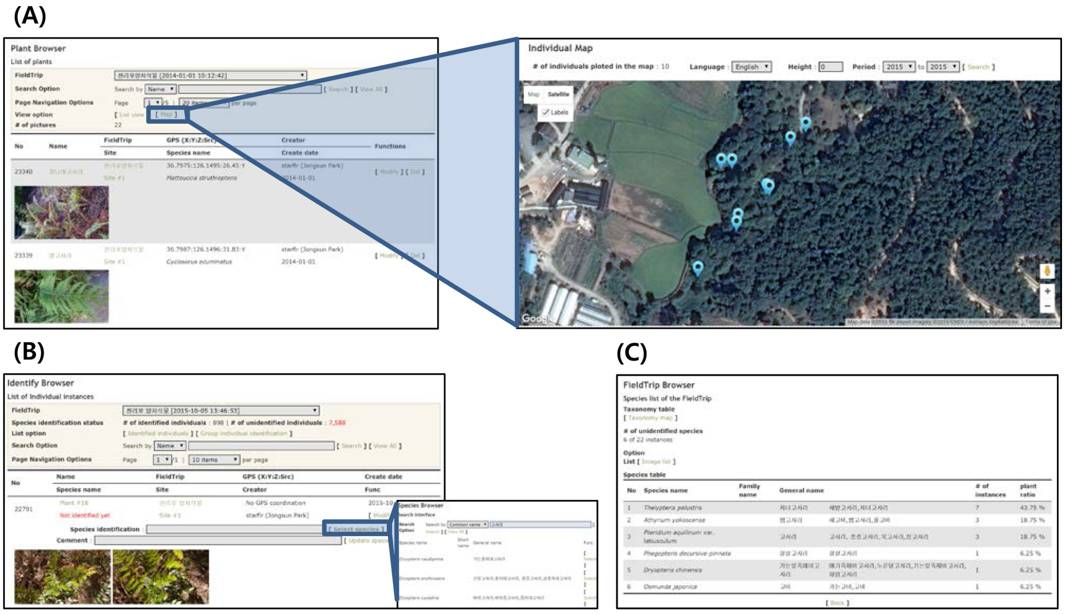

Figure 3. Web interface of the PlantGPS system. (A) Plant Browser provides a list of plants with pictures and their distribution on Google map. (B) Identifying plants with web interface. (C) Web interface of fieldtrip statistics.

Hierarchical structure of "Field trip-Site-Individual plant-Picture" is efficient enough to classify plants and pictures.

3.3. Upload collected data in PlantGPS

Collected information from field trips, sites, plants, pictures, and their GPS coordination are stored in the mobile device first. We may upload collected data to a server where Wi-Fi network is available. The PlantGPS system is designed to use Wi-Fi network for data uploading because the cost of cellular network (3G or 4G network) are high. In addition, cellular network is not so reliable in the field, especially in mountain area. Users may access the PlantGPS system with their personal account and password (Figure 2B) to access the web interface.

3.4. Management of collected data in a web interface of PlantGPS

Users may open the PlantGPS web site (http://www.plantdb.info/) to check and analyze collected information from mobile devices. It is possible to browse pictures of plants and plot locations of plants on the map (Figure 3A). Re-identification of plants and editing collection information are also possible with the menu bar of 'Species Identification' (Figure 3B). Plant identified by one user can be checked by another user who has permission in the PlantGPS system for multiple confirmations of the species. Statistics of the identified species in a field trip can be checked with "FieldTrip" browser (Figure 3C). With "Project" function, on-line collaboration among multiple users is also possible.

Example 1: Plants in Nangsae Island, an Island in Chollipo Arboretum

Using the PlantGPS system, we surveyed natural and transplanted plants in Nangsae Island adacent to the seashore of Chollipo arboretum in Taean-gun, Korea. The island is connected to the land when the tide is out. Therefore, native plants distributed in this island are similar to those in adjacent land. Since 1976, some cultivated plants and Korean native plants have been transplanted there for the purpose of ornamentation and conservation (Song *et al.*, 1999). Based on two times of surveys (June 21 and August 2, 2015), pictures of 89 plant individuals with GPS coordination were successfully collected (Table 1; Figure 4A). Identification of plants was done on site by a person who attended the survey. The identification

Table 1. List of identified angiosperm species in Nangsae Island in this study.

No	Taxa	Family	Common name (Korean)	Year of transplanted
1	*Aster spathulifolius* Maxim.	Asteraceae	해국	-
2	*Elaeagnus macrophylla* Thunb.	Elaeagnaceae	보리밥나무	-
3	*Quercus dentata* Thunb.	Fagaceae	떡갈나무	-
4	*Paederia scandens* (Lour.) Merr.	Rubiaceae	계요등	-
5	*Smilax china* L.	Smilacaceae	청미래덩굴	-
6	*Rhus javanica* L.	Anacardiaceae	붉나무	-
7	*Saussurea odontolepis* Sch. Bip. ex Herder	Asteraceae	빗살서덜취	-
8	*Rhododendron mucronulatum* Turcz.	Ericaceae	진달래	-
9	*Vitis ficifolia* var. *sinuata* (Regel) H. Hara	Vitaceae	까마귀머루	-
10	*Carpinus turczaninowii* Hance	Betulaceae	소사나무	-
11	*Dendranthema indicum* (L.) Des Moul.	Asteraceae	감국	-
12	*Ilex cornuta* Lindl. & Paxton	Aquifoliaceae	호랑가시나무	1980
13	*Lindera erythrocarpa* Makino	Lauraceae	비목나무	-
14	*Pinus thunbergii* Parl.	Pinaceae	곰솔	-
15	*Pueraria lobata* (Willd.) Ohwi	Fabaceae	칡	-
16	*Atractylodes ovata* (Thunb.) DC.	Asteraceae	삽주	-
17	*Leibnitzia anandria* (L.) Turcz.	Asteraceae	솜나물	-
18	*Festuca ovina* L.	Poaceae	김의털	-
19	*Lonicera japonica* Thunb.	Caprifoliaceae	인동	-
20	*Machilus thunbergii* Siebold & Zucc.	Lauraceae	후박나무	1980
21	*Albizia julibrissin* Durazz.	Fabaceae	자귀나무	-
22	*Platycarya strobilacea* Siebold & Zucc.	Juglandaceae	굴피나무	-
23	*Prunus sargentii* Rehder	Rosaceae	산벚나무	-
24	*Cocculus trilobus* (Thunb.) DC.	Menispermaceae	댕댕이덩굴	-
25	*Ampelopsis brevipedunculata* (Maxim.) Trautv.	Vitaceae	개머루	-
26	*Hemerocallis fulva* (L.) L.	Xanthorrhoeaceae	원추리	-
27	*Asarum sieboldii* Miq.	Aristolochiaceae	족도리풀	-
28	*Ilex integra* Thunb.	Aquifoliaceae	감탕나무	1980
29	*Toxicodendron trichocarpum* (Miq.) Kuntze	Anacardiaceae	개옻나무	-
30	*Zanthoxylum piperitum* (L.) DC.	Rutaceae	초피나무	-
31	*Adenophora triphylla* var. *japonica* (Regel) H. Hara	Campanulaceae	잔대	-
32	*Chenopodium album* var. *centrorubrum* Makino	Amaranthaceae	명아주	-
33	*Prunus japonica* var. *nakaii* (H. Lév.) Rehder	Rosaceae	이스라지나무	-
34	*Rhaphiolepis indica* var. *umbellata* (Thunb.) Ohashi	Rosaceae	다정큼나무	1976
35	*Rubia cordifolia* var. *pratensis* Maxim.	Rubiaceae	갈퀴꼭두선이	-
36	*Solidago virgaurea* ssp. *asiatica* Kitam. ex H. Hara	Asteraceae	미역취	-
37	*Iris dichotoma* Pall.	Iridaceae	대청부채	-
38	*Kalopanax septemlobus* (Thunb.) Koidz.	Araliaceae	음나무	-

of plants has been confirmed by different persons based on pictures deposited on the server without attending the survey. We successfully identified all collected pictures for 39 plant species from 25 families. All these data can be accessed via the Nangsae Island database (http://nangsae.chollipo.info/) through the PlantGPS system.

From 1976 to 1996, 718 trees including 708 broad-leaved evergreen trees (26 species) had been transplanted in Nangsae Island. In the first manual survey for monitoring those transplanted trees in 1999, 15 species (121 individuals) were identified (Song *et al.*, 1999). Only four species that might have survived from those transplanted plants were identified in the current survey (Table 2). One of them is a whole-leaf Indian hawthorn [*Rhaphiolepis indica* var. *umbellata*

Figure 4. Distribution of transplanted plants in Nangsae Island. (A) A map of 89 observed plant individuals in Nangsae Island. Blue pin indicates location of each plant individual. (B) Distribution of *Ilex conuta* in Nangsae Island. Red part indicates an area where trees have been transplanted (Song, Bae *et al.*, 1999).

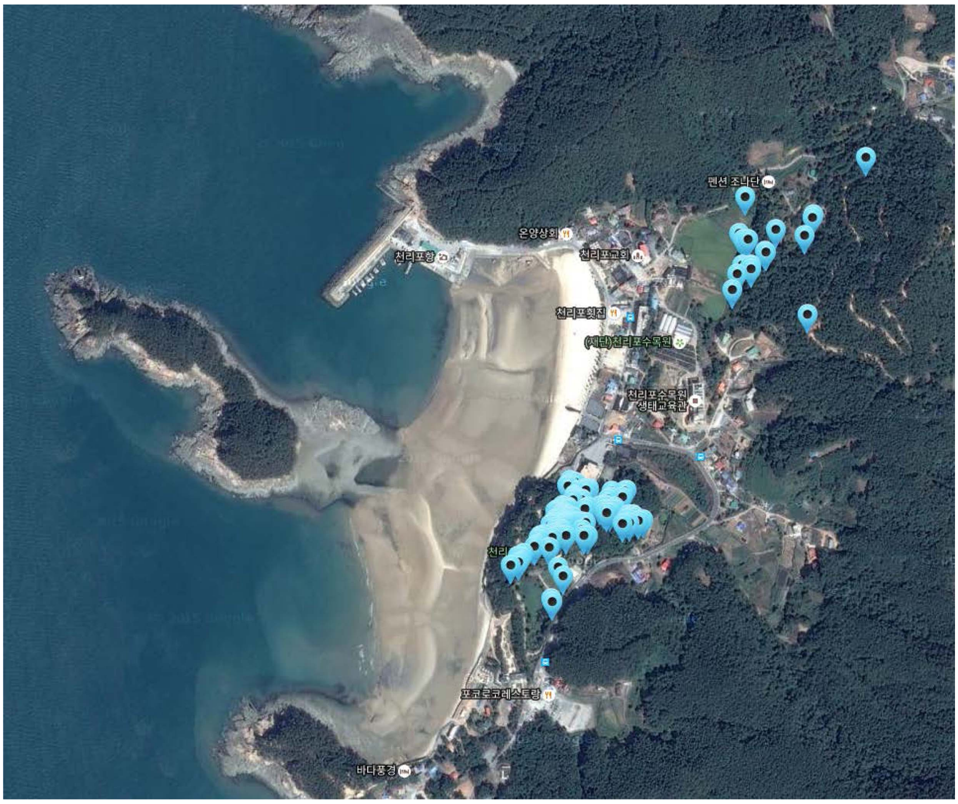

Figure 5. Distribution of ferns in Chollipo arboretum (main area). Distribution of 89 fern individuals surveyed in Chollipo arboretum. Blue pin indicates each fern individual.

Table 2. List of identified fern species in Chollipo arboretum (main area) in this study.

No	Taxa	Family	Common name (Korean)	# of individuals
1	*Athyrium niponicum* (Mett.) Hance	Athyriaceae	개고사리	24
2	*Cyrtomium fortunei* J. Sm.	Dryopteridaceae	쇠고비	16
3	*Cyclosorus acuminatus* (Houtt.) Nakai ex H. Ito	Thelypteridaceae	별고사리	14
4	*Matteuccia struthiopteris* (L.) Tod.	Onocleaceae	청나래고사리	13
5	*Phegopteris decursive-pinnata* (H. C. Hall) Fee	Thelypteridaceae	설설고사리	12
6	*Thelypteris palustris* (Salisb.) Schott	Thelypteridaceae	처녀고사리	9
7	*Dryopteris crassirhizoma* Nakai	Dryopteridaceae	관중	8
8	*Onoclea sensibilis* L.	Onocleaceae	야산고비	8
9	*Asplenium incisum* Thunb.	Aspleniaceae	꼬리고사리	7
10	*Athyrium yokoscense* (Franch. & Sav.) H. Christ	Athyriaceae	뱀고사리	7
11	*Dryopteris monticola* (Makino) C. Chr.	Dryopteridaceae	왕지네고사리	6
12	*Pteris multifida* Poir.	Pteridaceae	봉의꼬리	6
13	*Polypodium vulgare* L.	Polypodiaceae	미역고사리	5
14	*Hypolepis punctata* (Thunb.) Mett. ex Kuhn	Dennstaedtiaceae	점고사리	5
15	*Dryopteris chinensis* (Baker) Koidz.	Dryopteridaceae	가는잎족제비고사리	5
16	*Dryopteris uniformis* (Makino) Makino	Dryopteridaceae	곰비늘고사리	5
17	*Dryopteris pacifica* (Nakai) Tagawa	Dryopteridaceae	큰족제비고사리	5
18	*Dryopteris bissetiana* (Baker) C. Chr.	Dryopteridaceae	산족제비고사리	4
19	*Pteridium aquilinum* var. *latiusculum* (Desv.) Underw. ex A. Heller	Dennstaedtiaceae	고사리	4
20	*Polystichum polyblepharum* (Roem. ex Kunze) C. Presl	Dryopteridaceae	나도히초미	4
21	*Osmunda claytoniana* L.	Osmundaceae	음양고비	3
22	*Osmunda japonica* Thunb.	Osmundaceae	고비	3
23	*Plagiogyria euphlebia* (Kunze) Mett.	Plagiogyriaceae	꿩고사리	2
24	*Arachniodes standishii* (T. Moore) Ohwi	Dryopteridaceae	일색고사리	2
25	*Dryopteris erythrosora* (D. C. Eaton) Kuntze	Dryopteridaceae	홍지네고사리	2
26	*Cyrtomium falcatum* (L. f.) C. Presl	Dryopteridaceae	도깨비고비	2
27	*Microlepia strigosa* (Thunb.) C. Presl	Dennstaedtiaceae	돌토끼고사리	2
28	*Athyrium sinense* Rupr.	Athyriaceae	참새발고사리	2
29	*Polystichum ovatopaleaceum* var. *coraiense* (H. Christ) Sa. Kurata	Dryopteridaceae	참나도히초미	2
30	*Diplazium nipponicum* Tagawa	Athyriaceae	곶섬잔고사리	2
31	*Lygodium japonicum* (Thunb.) Sw.	Lygodiaceae	실고사리	2
32	*Coniogramme intermedia* Hieron.	Pteridaceae	고비고사리	2
33	*Dryopteris tokyoensis* (Matsum. ex Makino) C. Chr.	Dryopteridaceae	느리미고사리	1
34	*Equisetum hyemale* L.	Equisetaceae	속새	1
35	*Asplenium scolopendrium* L.	Aspleniaceae	골고사리	1
36	*Deparia japonica* (Thunb.) M. Kato	Athyriaceae	진고사리	1
37	*Dryopteris sacrosancta* Koidz.	Dryopteridaceae	애기족제비고사리	1
38	*Deparia lancea* (Thunb.) Fraser-Jenk.	Athyriaceae	버들참빗	1
39	*Polystichum tripteron* (Kunze) C. Presl	Dryopteridaceae	십자고사리	1
40	*Adiantum pedatum* L.	Pteridaceae	공작고사리	1
41	*Thelypteris beddomei* (Baker) Ching	Thelypteridaceae	가는잎처녀고사리	1
42	*Arachniodes aristata* (G. Forst.) Tindale	Dryopteridaceae	가는쇠고사리	1
43	*Coniogramme japonica* (Thunb.) Diels	Pteridaceae	가지고비고사리	1
44	*Osmunda cinnamomea* L.	Osmundaceae	꿩고비	1
45	*Lemmaphyllum microphyllum* C. Presl	Polypodiaceae	콩짜개덩굴	1
46	*Marsilea quadrifolia* L.	Marsileaceae	네가래	1
47	*Cornopteris christenseniana* (Koidz.) Tagawa	Athyriaceae	지리산숲고사리	1
48	*Gymnocarpium jessoense* (Koidz.) Koidz.	Cystopteridaceae	산토끼고사리	1
50	*Athyrium niponicum* 'Pictum'	Athyriaceae	개고사리 재배종 'Pictum'	1
51	*Cornopteris decurrenti-alata* (Hook.) Nakai	Athyriaceae	뿔고사리	1

(Thunb.) Ohashi]. It has been reported that all transplanted trees of whole-leaf Indian hawthorn are withered in 1999 (Song *et al.*, 1999). In addition, all four species were found near the original transplanted area. It is uncertain whether these trees are survivors or are seedlings from original transplanted plants (Figure 4B). It is clear that these four species have fully adapted to the environment of this island. All these data can be accessed via the Nangsae Island database (http://nangsae.chollipo.info/) supported by the PlantGPS system.

Example 2: Ferns in Chollipo arboretum

As a second example, we surveyed fern species inside Chollipo arboretum. In early 1980s, many fern species were introduced into Chollipo arboretum for displaying purpose. Some species are naturalized and dispersed inside Chollipo arboretum. With intensive survey using the PlantGPS system, we found 224 fern individuals (Figure 5). A total of 51 species were identified from 211 ferns (Table 2). Interestingly, 10 fern species from nine genera have never been reported in natural habitat around the area of Chollipo arboretum (Table 2), indicating that these ferns might have successfully adapted to the environment of this area after the transplantation. Fern distribution data in Chollipo Arboretum collected by the PlantGPS system can be browsed in Chollipo Fern Database (http://fern.chollipo.info/).

3.5. Conclusion and further studies

The PlantGPS system has been developed as an efficient tool to instantly collect plant distribution data using mobile devices. In the two test projects for the application of the PlantGPS, most plants were successfully identified by different researchers without attending the surveys based on pictures in the database, indicating that this system is an efficient tool for instant survey of plant distribution in a specific region. We plan to improve our PlantGPS system to accommodate better quality pictures and manage additional environmental conditions such as temperature, humidity, and light intensity in the future. Our long-term goal is to monitor specific area (e.g., Bukhansan National Park) for more than 10 years with the PlantGPS system, including high quality pictures and their accompanying data. This can be a model project to understand global climate change and make strategy to overcome its effect.

Acknowledgements

This work was supported by a grant (NIBR No. 2013-02-071) entitled ‘Researcher capacity-building project for R&D on biological resources to prepare for the Nagoya Protocol.’ from the National Institute of Biological Resources (NIBR) of the Ministry of Environment (MOE), Republic of Korea. We thank Nayoung Kim for helping field works of this project.

References

Baskauf, S. J. and Kirchoff, B. K. 2008. Digital plant images as specimens: toward standards for photographing living plants. Vulpia 7: 16-30.

Beckage, B., Osborne. B., Gavin, D. G., Pucko, C., Siccama, T., and Perkins, T. 2008. A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. Proceedings of the National Academy of Sciences 105: 4197-4202.

Choi, H. J., Jang, J. E., and Cheong, S. W. 2014. Original article: First record of *Myriophyllum oguraense* Miki (Haloragaceae) in Korea. Korean Journal of Plant Taxonomy 44: 77-80.

Cope, J. S., Corney, D., Clark, J. Y., Remagnino, P., and Wilkin, P. 2012. Plant species identification using digital morphometrics: a review. Expert Systems with Applications 39: 7562-73.

Du, J. X., Wang, X. F., and Zhang, G. J. 2007. Leaf shape based plant species recognition. Applied Mathematics and Computation 185: 883-893.

Han, B. H., Lee, K. J., Jang, J. H., and Jung, T. J. 2009. A study on ecological characteristics and changes of back garden in Changdeokgung. Proceedings of the Korean Society of Environment and Ecology Conference 2009: 133-136.

Lenoir, J., Gégout, J.-C., Marquet, P., de Ruffray, P., and Brisse, H. 2008. A significant upward shift in plant species optimum elevation during the 20th century. Science 320: 1768-1771.

Miller-Rushing, A. J., Primack, R. B., Primack, D., and Mukunda, S. 2006. Photographs and herbarium specimens as tools to document phenological changes in response to global warming. American Journal of Botany 93: 1667-1674.

Park, Y. H., Park, S. H., and Yoo, K. O. 2014. Original article : A newly naturalized species in Korea: *Amaranthus powellii* S. Watson (Amaranthaceae). Korean Journal of Plant Taxonomy 44: 132-135.

Song, K. H., Bae, J. K., and Jung, M. Y. 1999. Ecological monitoring for the restoration of evergreen broad-leaved forest in Taksom Chollipo Arboretum (1). Korean Journal of Environment and Ecology 1999: 74-76.

Sturm, M., Racine, C., kand Tape, K. 2001. Climate change: increasing shrub abundance in the Arctic. Nature 411: 546-547.