Phenological Eyes Network (PEN) and ground-truthing activity for satellite remote sensing

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Abstract – To test and validate the satellite remote sensing, we established a robust, universal, continuous, and long-term ground observation system and network for multiple ecosystems over the world: "Phenological Eyes Network" (PEN). In the present study, we show the observation system, logic, concept, philosophy, findings, and networks of PEN.

Keywords: Phenological Eyes Network, ground-truthing, satellite remote sensing, ecosystem, digital camera, spectroradiometer, sunphotometer

1. Introduction

Satellite remote sensing is a useful method to evaluate the ecosystem structure and functions with a high spatio-temporal resolution from plot to global scales. However, from the *in situ* ecological research viewpoint, the satellite remote sensing method has not been sufficiently tested or validated by the ground truth observations. This may be due to the following three reasons. (1) Data gap issue: Field and remote sensing scientists have not been collected the long-term continuous *in situ* data to validate satellite remote sensing. (2) Missing link issue: We have not yet understood the ecosystem structure and functions on the ground level to provide the eco-physiological interpretation for the satellite remote sensing. (3) Poor communication issue: Field and remote sensing scientists have not been collaborated and communicated well. These issues are a fatal barrier to bridge a gap between *in situ* and satellite remote sensing observations. To solve these issues, we require a robust, universal, continuous, and long-term ground observation system and network for multiple ecosystems. We also should collaborate with various scientists' networks and communities such as ILTER and FLUXNET. For the sake of it, we have established "Phenological Eyes Network" (PEN; Tsuchida *et al*. 2005, Nishida 2007) in 2003.

2. Observation system

PEN basically consists of the following three observation systems: (1) Automatic-capturing Digital Fish-eye Camera ("ADFC" system: Nikon CoolPix 4300 or 4500 digital camera, Nikon, Tokyo, Japan; FC-E8 fisheye lens, Nikon; SPC31A controller, Hayasaka Rikoh, Sapporo, Japan) for monitoring vegetation dynamics including phenology of foliage and canopy growth and sky conditions, (b) Hemi-Spherical Spectro-Radiometer ("HSSR" system: MS700 or 720 spectral radiometer, Eko Instruments Co., Tokyo, Japan; CHS-AR reversible stage, Hayasaka Rikoh) for measuring vegetation's optical properties such as spectral reflectance and vegetation indices, and (c) SunPhotometer ("SP" system: POM-02 sunphotometer, Prede Co., Tokyo, Japan) for measuring atmospheric optical properties such as aerosol optical thickness (Figure 1). These systems are automatically controlled by a personal computer. In some sites, these systems can be accessed and controlled via the Internet. A more complete description of the ADFC and HSSR systems is available in Motohka *et al.* (2010).

3. PEN sites and data archive

PEN sites have been set up various terrestrial ecosystem sites in Japan, South Korea, China, Malaysia, United Kingdom, Germany, and USA (Table 1). In addition, new sites are scheduled to establish at a rice paddy in Bangladesh, evergreen coniferous forests in Alaska and United Kingdom, and an evergreen broad-leaved forest in Hawaii.

Summary of PEN data are basically publicly available on the Internet (http://www.pheno-eye.org). The original data are open to the PEN community members. However, anybody can join us if they want (please email to pen_inf@m.aist.go.jp). Our data request policy is that the users should contact us and the site PI preliminarily if you have a plan to use PEN data for your presentation or article.

Table 1. Summary of the number of PEN systems installed in various terrestrial ecosystems

	ADFC	HSSR	SP
Evergreen broad-leaved forest	1 (Malaysia)	Not available	Not available
Deciduous broad-leaved forest	5 (Japan, United Kingdom, Germany, South Korea)	2 (Japan, South Korea)	1 (Japan)
Evergreen coniferous forest	4 (Japan, Alaska)	2 (Japan)	Not available
Deciduous coniferous forest	1 (Japan)	1 (Japan)	1 (Japan)
Mixed forest	3 (Japan)	Not available	Not available
Grassland	2 (Japan)	1 (Japan)	1 (Japan)
Rice paddy	2 (Japan, China)	1 (Japan)	Not available

ADFC: camera, HSSR: spectral radiometer, SP: sunphotometer

4. Examples of PEN study

Validation of the phenology observation by using vegetation index

To test the criterion for timing of leaf expansion and defoliation by using normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI), we examined the relationship between these vegetation indices and tree phenology during leaf expansion and defoliation by simultaneously observing the ADFC and HSSR in a cool-temperate deciduous broad-leaved forest, Takayama site in Japan. As a result, we found that NDVI values of 0.6–0.7 and EVI values of 0.4-0.5 can serve as potential criteria for detecting the timing of leaf expansion. In contrast, no NDVI and EVI values can serve as potential criteria for that of defoliation. Our findings identified that the previously reported criterion for the timing of leaf expansion and defoliation by using satellite-observed NDVI (the maximum rate of growth or reduction of vegetation indices and a value midway between the year's maximum and minimum values) are misleading in a deciduous broad-leaved forest (Nagai *et al.* 2010).

Development of a new phenology detectable vegetation index

We examined the availability, generality, and robustness of the green-red ratio vegetation index (GRVI, Falkowski *et al*. 2005) by using the simultaneous observed ADFC and HSSR in deciduous broad-leaved and coniferous forest, rice paddy, and grassland sites. GRVI is obtained by the following equation: GRVI = (Rgreen – Rred) / (Rgreen + Rred), where Rgreen and Rred are the reflectance bands of green and red, respectively. As a result, we identified that GRVI is a promising new vegetation index that we can detect specific responses to subtle disturbance and the difference of ecosystem types (Motohka *et al.* 2010).

5. Conclusion

Our long-term multiple ecosystems observation approach based on PEN provides many scientific evidences to develop the satellite remote sensing observation from the *in situ* ecological research viewpoint. We also would like to ask many networks and communities such as the JaLTER (ecological network), JapanFlux (flux network), JAXA (space agency), and JAMSTEC (marine and earth science agency) collaborations in Japan, J- and AP-BON (Japan and Asian Pacific biodiversity observation network), and land product validation subgroup in NASA.

References

M.J. Falkowski, P.E. Gessler, P. Morgan, A.T. Hudak, and A.M.S. Smith, "Characterizing and mapping forest fire fuels using ASTER imagery and gradient modeling", Forest Ecology and Management, vol 217, p.p. 129-146, 2005.

T. Motohka, K.N. Nasahara, H. Oguma, and S. Tsuchida, "Applicability of green-red vegetation index for remote sensing of vegetation phenology", Remote Sensing, vol 2, p.p. 2369-2387, 2010.

S. Nagai, K.N. Nasahara, H. Muraoka, T. Akiyama, and S. Tsuchida, "Field experiments to test the use of the normalized difference vegetation index for phenology detection", Agricultural and Forest Meteorology, vol 150, p.p. 152-160, 2010.

K. Nishida, "Phenological Eyes Network (PEN) --- A validation network for remote sensing of the terrestrial ecosystems", AsiaFlux Newsletter Issue 21, p.p. 9-13 (http://www.asiaflux.net/newsletter.htmlnewsletter.html), 2007.

S. Tsuchida, K. Nishida, K. Iwao, W. Kawato, H. Oguma, and A. Iwasaki, "Phenological Eyes Network for validation of remote sensing data", Journal of the Remote Sensing Society of Japan, vol 25(3), p.p. 282-288, 2005 (in Japanese with English summary).

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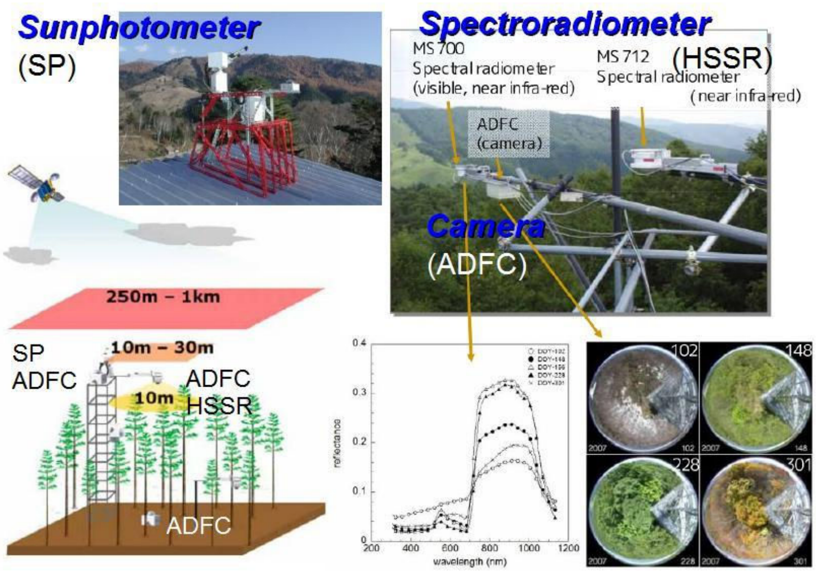

Figure 1. Summary of the PEN observation system.