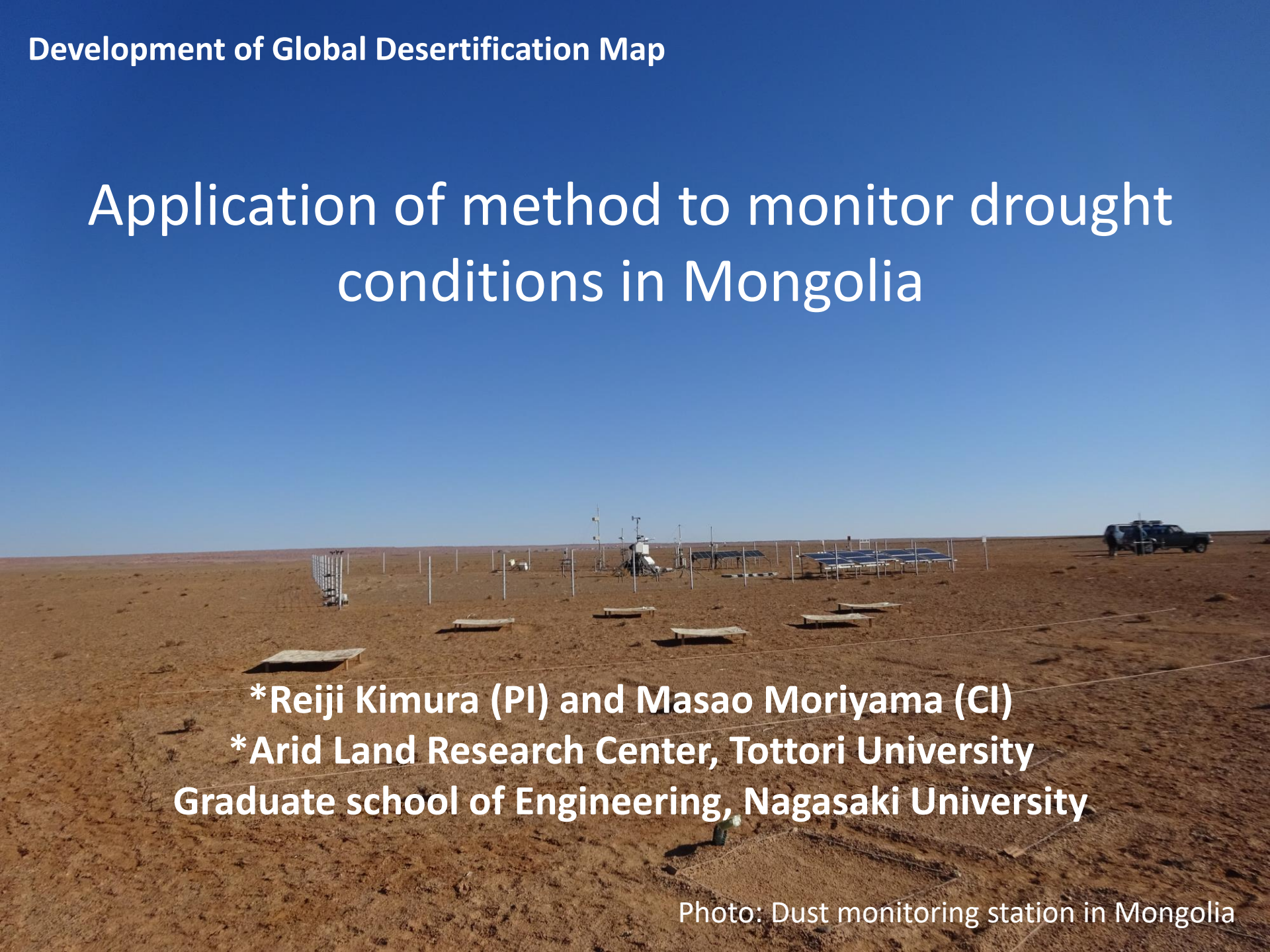
Application of method to monitor drought conditions in Mongolia



***Reiji Kimura (PI) and Masao Moriyama (CI)**
***Arid Land Research Center, Tottori University**
Graduate school of Engineering, Nagasaki University

Photo: Dust monitoring station in Mongolia

Background and objectives

When arid regions was classified, **"Aridity Index"** based on the climatic water balance is general

however…

This is just a climatic index, not an actual aridity

then, my idea is…

by comparing actual aridity monitored by satellite（SbAI）with climatic aridity index,

We examined to monitor the drought conditions in Mongolia using SbAI and NDVI.

Calculation of aridity index (AI)

In United Nations Environmental Program（UNEP）,
Aridity Index＝Annual rainfall／Annual potential evapotranspiration
is used for definition of arid regions.

■ Annual rainfall

GPCC's daily data from 2001 to 2013 were downloaded from the NOAA Earth System Research Laboratory with a grid scale of 1 deg.

■ Annual potential evapotranspiration (ETp)

The ETp was calculated as by the Thornthwaite method, which has also been used by the UNEP (1992, 1997):

$$\mathrm{ETp} = 1.6\left(\frac{10t_{\mathrm{i}}}{I}\right)^{a}\frac{N}{12}$$

t_{i} is the monthly averaged temperature (°C), N is the monthly averaged possible duration of sunshine (h), and I is the temperature efficiency index.

Data were downloaded from the NCEP with a grid scale of 1 deg.

About SbAI（Satellite based Aridity Index） by Kimura and Moriyama (2014)

$$SbAI = \frac{\Delta T_s}{R_{\max}}$$

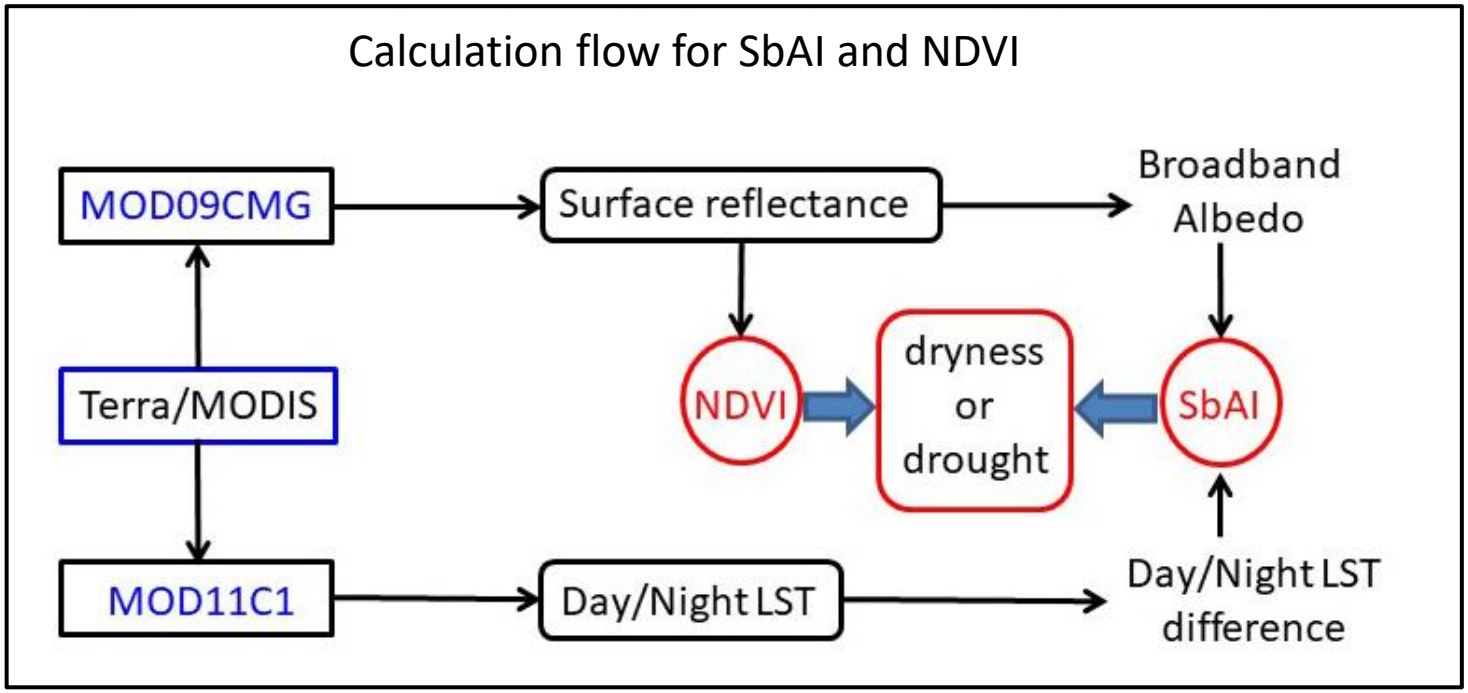
$$R_{\max} = (1-r)S_0 \cos(\theta_c)$$

Physical meanings

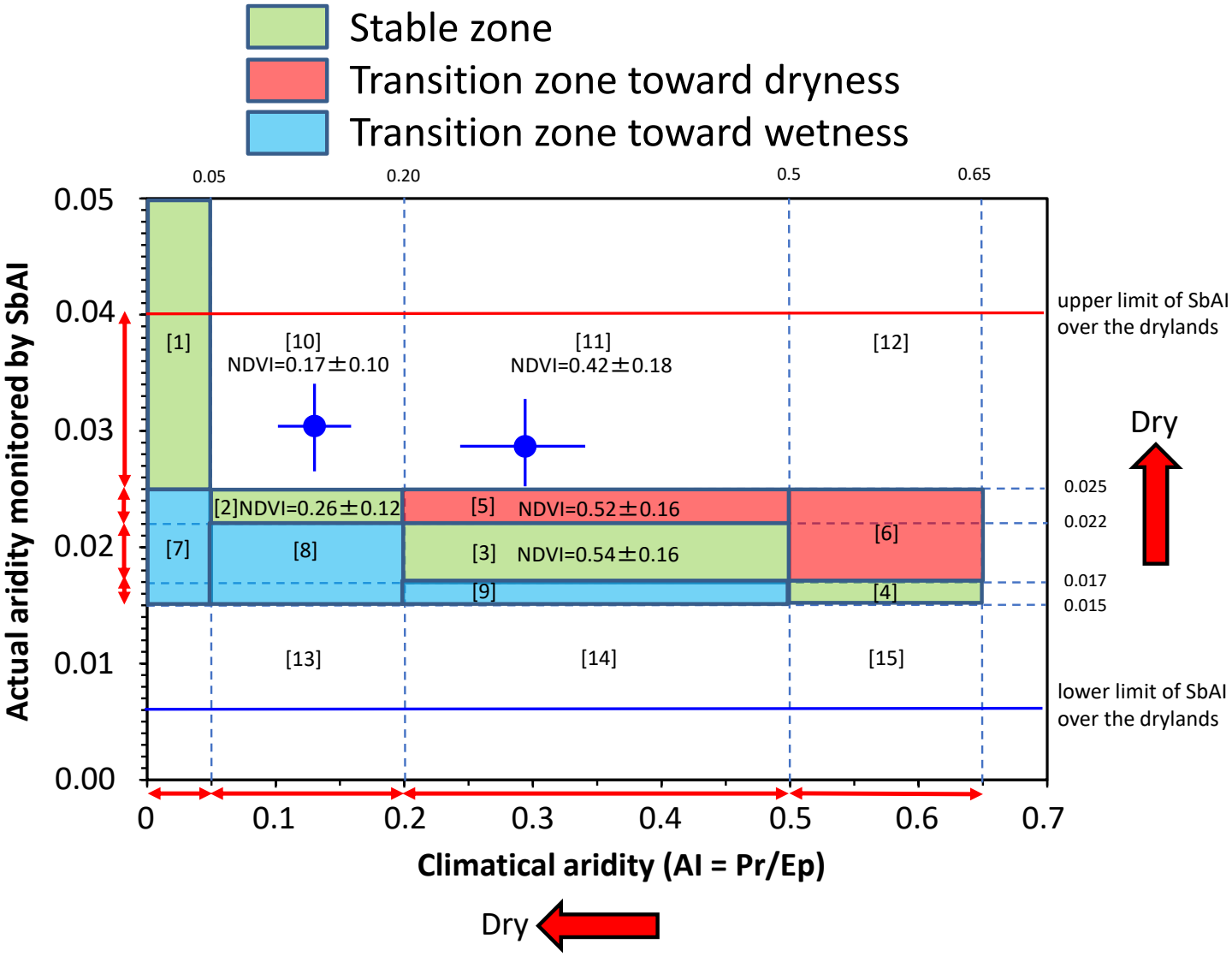
- reciprocal of heat capacity
- ratio of amplitude in respective sine curve
- ratio of radiant sensitivity to the LST change

※ For the dry surface, SbAI becomes large.

ΔT_s is the Day/Night land surface temperature difference, and R_{max} is the absorbed solar radiation at the culmination. r, S_0 and θ_c means the broadband albedo of the surface, the solar constant and the solar zenith at the culmination.



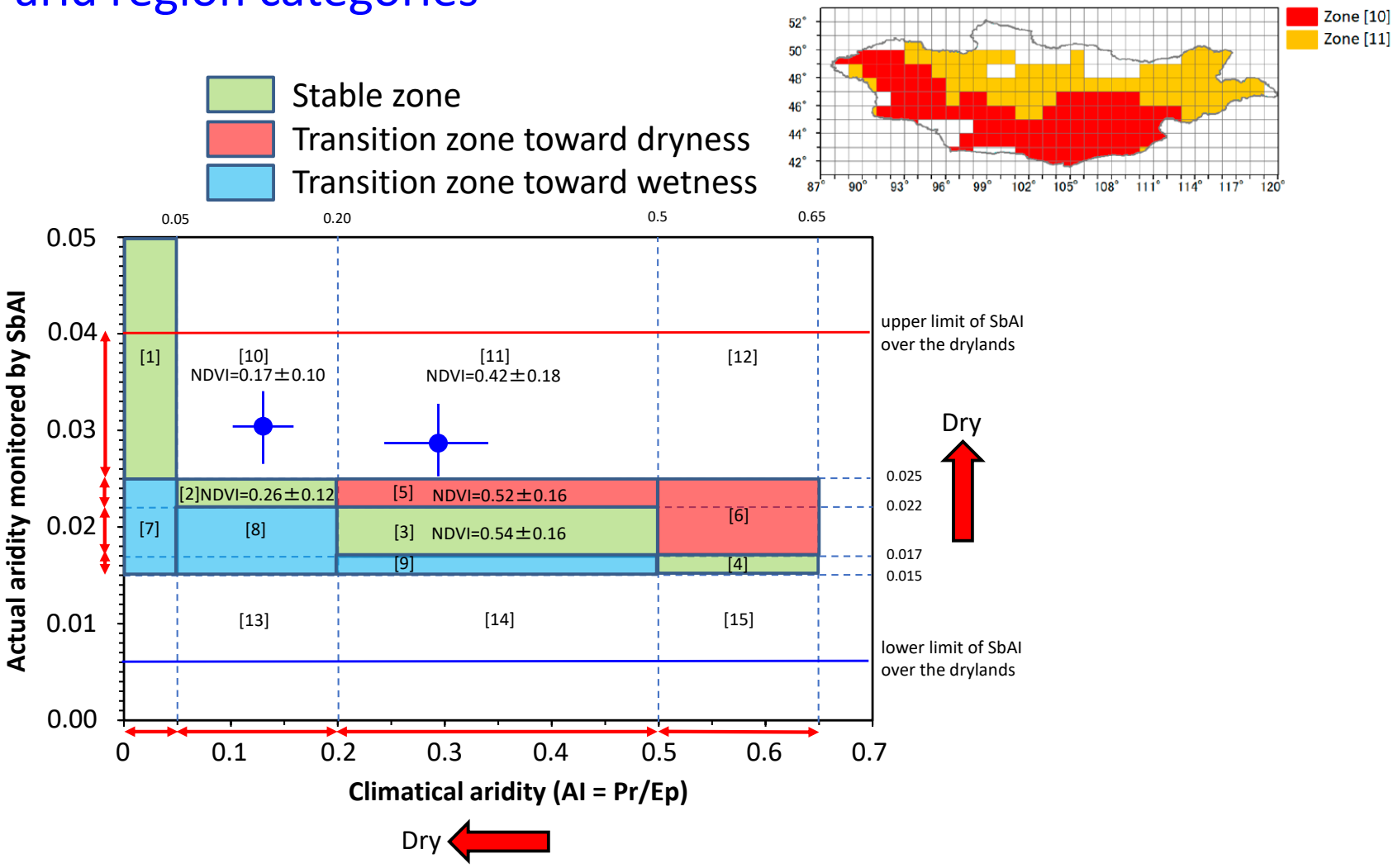
Method developed for detecting drought conditions based on the water balance concept



Results

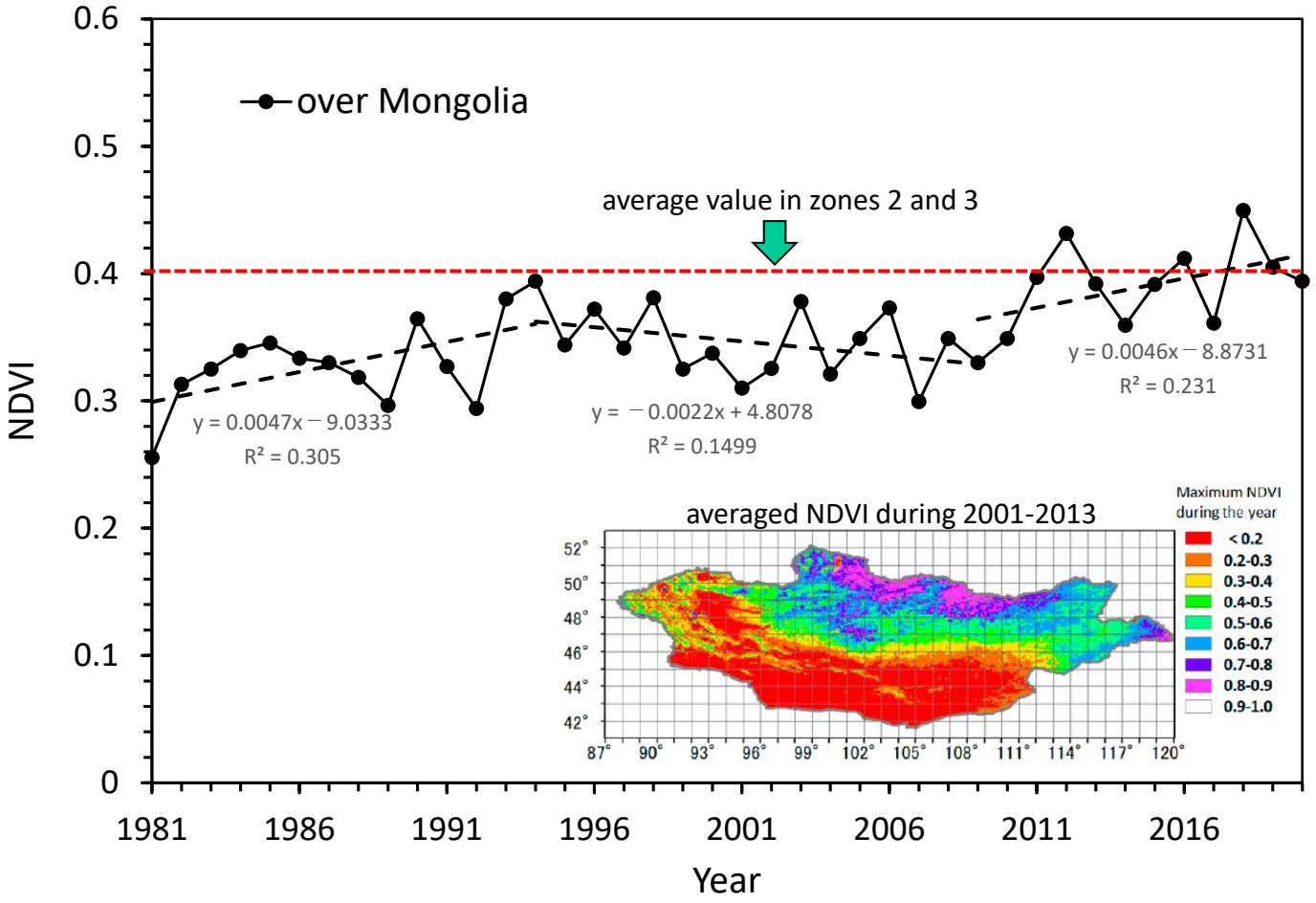
Photo : Night in Mongolia

Relationship between the AI and SbAI, averaged over 2001–2013, and the 15 arid region categories



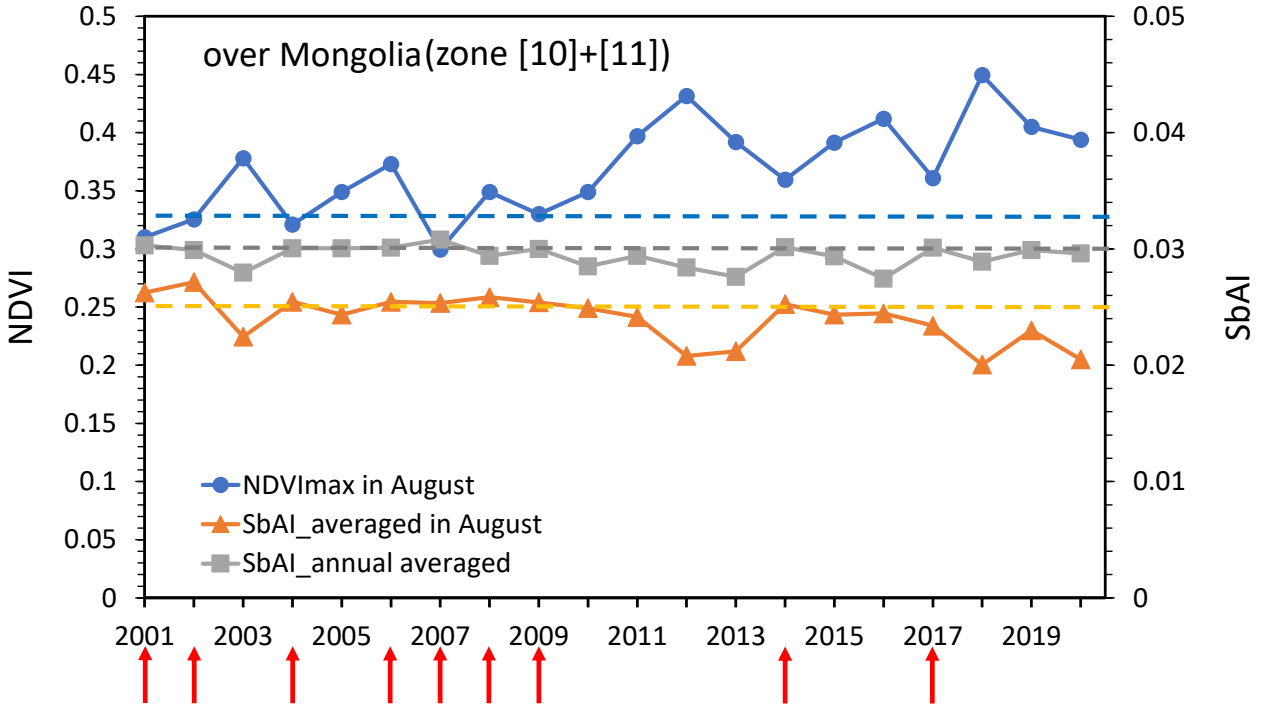
- In Mongolia (blue dots), the areas that should have been in zones 2 and 3 were in zones 10 and 11. This result indicates that the actual aridity in most of Mongolia was more severe than the climatic aridity.

Annual changes (1981–2020) of the $NDVI_{max}$ in August over Mongolia



- $NDVI_{max}$ decreased from 1994 to 2009. The decreasing trend of the $NDVI_{max}$ up to 2009 was presumably due to decreased precipitation.
- The peak value of the $NDVI_{max}$ was only 0.39 in 1994, less than the average value of 0.4 in zones 2 and 3.
- An increasing trend of the $NDVI_{max}$ after 2009 can be found clearly.

Annual changes (2001–2020) in the $NDVI_{max}$ in August, averaged SbAI in August, and annual averaged SbAI over Mongolia

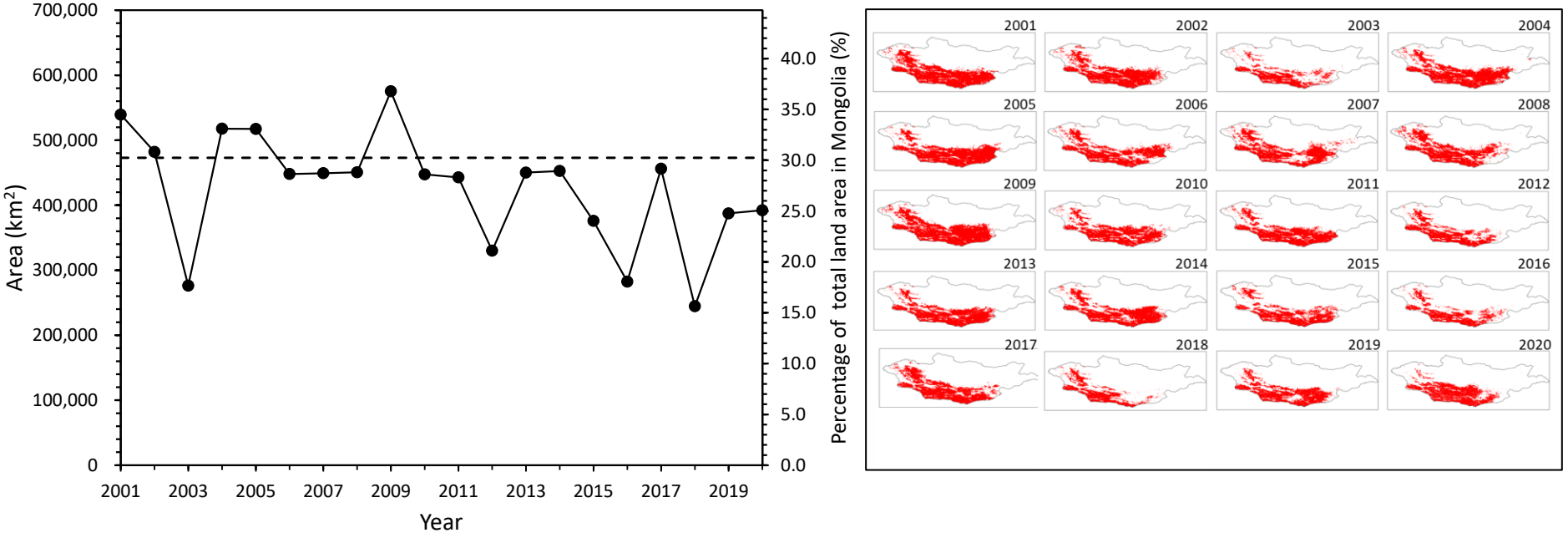


broken lines are the average values for the drought years (red arrows)

- Both of the SbAI values equaled or exceeded these broken line averages during 2001–2009, but they have fallen below the broken lines in many years since 2009.
- Drought years can be simply detected as follows:

$NDVI_{max} \leq 0.33$
averaged SbAI in August ≥ 0.025
annual averaged SbAI ≥ 0.030.

Annual changes of areas of degraded land and percentage of total land area in Mongolia



- Degraded land area, defined as annual $NDVI_{max} < 0.2$ and annual averaged SbAI > 0.025,has decreased, especially since 2009.
- Degraded land area was small in 2003, 2012, 2016, and 2018 but large in 2001, 2002, 2004, 2005, and 2009, which corresponded to the major drought years.
- The defined degraded land area should have been in zones 1 and 10. Therefore, this method will be useful for general detection in very severe drought condition.

Summary

- The $NDVI_{max}$ was small compared to the $NDVI_{max}$ values in other arid and semi-arid regions.
- The $NDVI_{max}$ had been decreasing up to 2010 after peaking in 1994. The $NDVI_{max}$ was small even at its peak value of 0.39 in 1994, and it did not reach its averaged value of 0.4 in zones [2] and [3].
- The SbAI during the summer was relatively small (wet). However, the SbAI through the year was large (dry). In Mongolia, most of the annual rainfall occurs from April to July, and that rainfall is reflected by the $NDVI_{max}$ in August.
- Under current conditions, the capacity of the land surface to retain water leads to a large SbAI because the concentrated summer rainfall affects the growth of vegetation.
- If the amount of precipitation, including precipitation during the winter, increases enough that the annual averaged SbAI decreases, the aridity of Mongolia will approach climatically stable conditions

Future development using GCOM-C

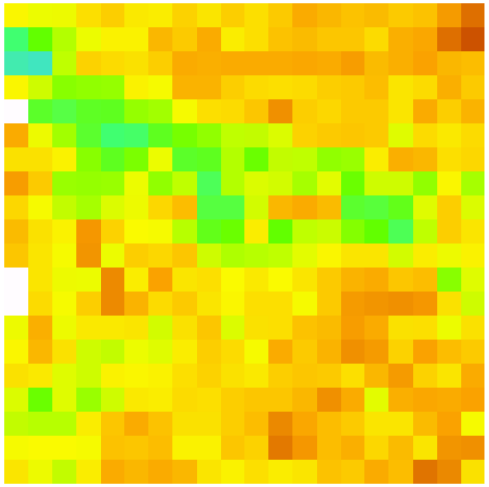
- Monitoring system should be created to manage data from MODIS to its successors such as the SGLI on the GCOM-C.

Necessary things to apply the SGLI are:

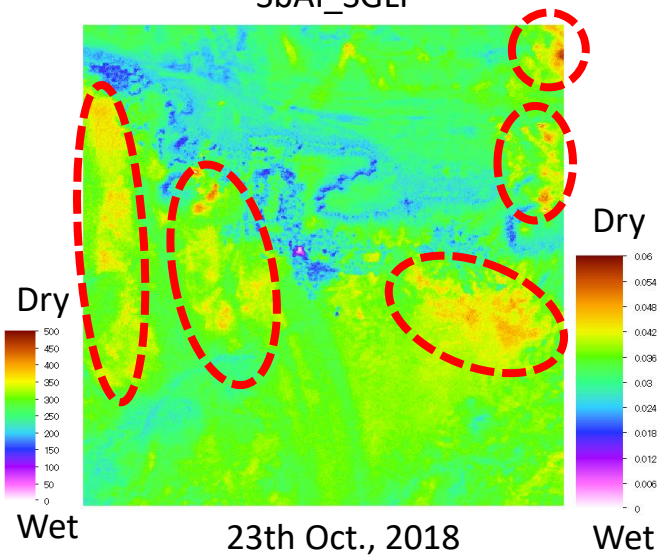
- Resolution is more sensitive.
- SGLI is difficult to monitor the daily SbAI globally, but…
- SGLI is appropriate to monitor the hot spot of degradation, desertification, and drought with high resolution on a daily basis.

Green areas are plant field

SbAI_MODIS



SbAI_SGLI



23th Oct., 2018

Comparison of SbAI by MODIS and SGLI in Dakhla Oasis of Egypt

Development of Global Desertification Map

Reiji Kimura (PI) and Masao Moriyama (CI)

Definition of degraded land area based on dust erodibility

- NDVI and SbAI can be used to indicate when a dust outbreak can occur, when

  NDVI < 0.2 and
  SbAI > 0.03.

  These threshold values of NDVI and SbAI for dust occurrence was defined on the basis of actual observations in China and Mongolia.
- Areas that meet both criteria was defined as degraded land.

Therefore…

- Degraded land area defined here include existing desert and both permanently and temporarily degraded land.

★ It should be noted that this criteria includes the meanings of both vegetation and soil degradation represented by wind erosion.

About SbAI（Satellite based Aridity Index） by Kimura and Moriyama (2014)

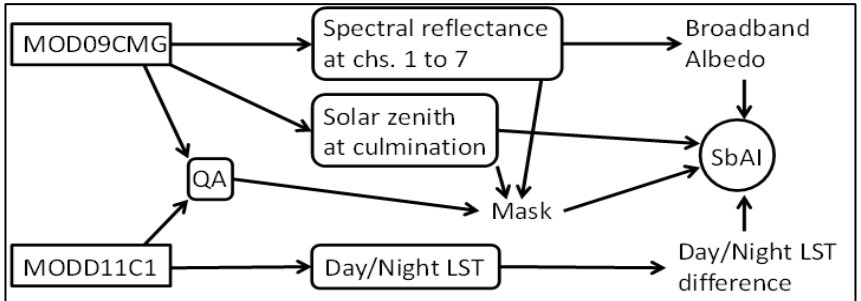
$$SbAI = \frac{\Delta T_s}{R_{\max}}$$

$$R_{\max} = (1-r)S_0 \cos(\theta_c)$$

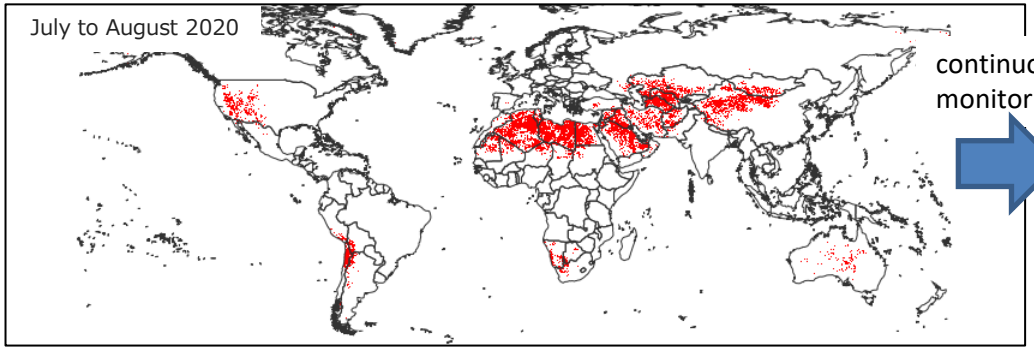
Physical meanings
- reciprocal of heat capacity
- ratio of amplitude in respective sine curve
- ratio of radiant sensitivity to the LST change

※ For the dry surface, SbAI becomes large.

ΔT_s is the Day/Night land surface temperature difference using the MODIS LST, and R_{max} is the absorbed solar radiation at the culmination. r, S_0 and θ_c means the broadband albedo of the surface, the solar constant and the solar zenith at the culmination.



Calculation flow for SbAI



continuous monitoring

Fig. 1 Example for degraded land area (colored by red).

open to the public: http://rkimura.alrc.tottori-u.ac.jp/aridregions/en2.html

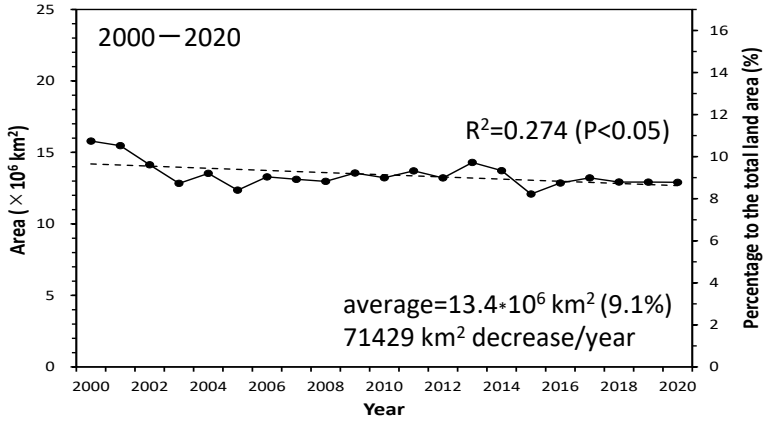


Fig. 2 Annual changes of areas of global degraded land (=aeolian desertification)