JICA Clean City Initiative

An EWS of landslide and slope failure by MEMS tilting sensor array

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SIP: Cross-ministerial Strategic Innovation Promotion Program,
The Cabinet Office of Japan

http://www.jst.go.jp/sip/dl/k07/booklet_en/27.pdf
http://www.jst.go.jp/sip/k07_en.html

JICA Clean City Initiative

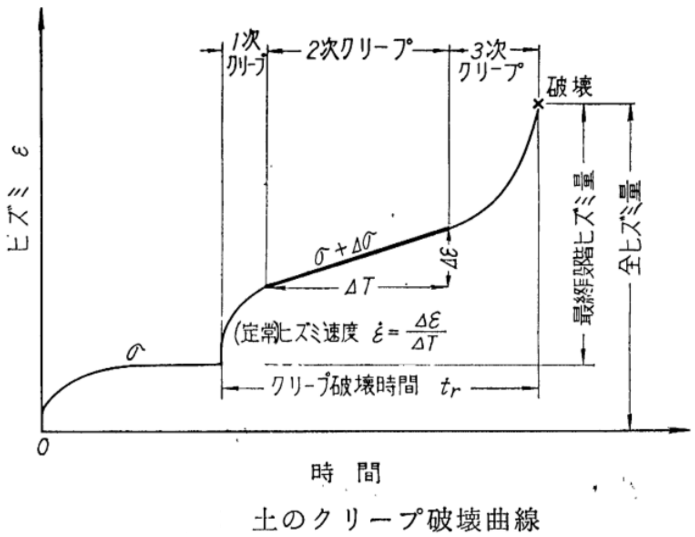
A success EW case of dam site slope failure in Japan

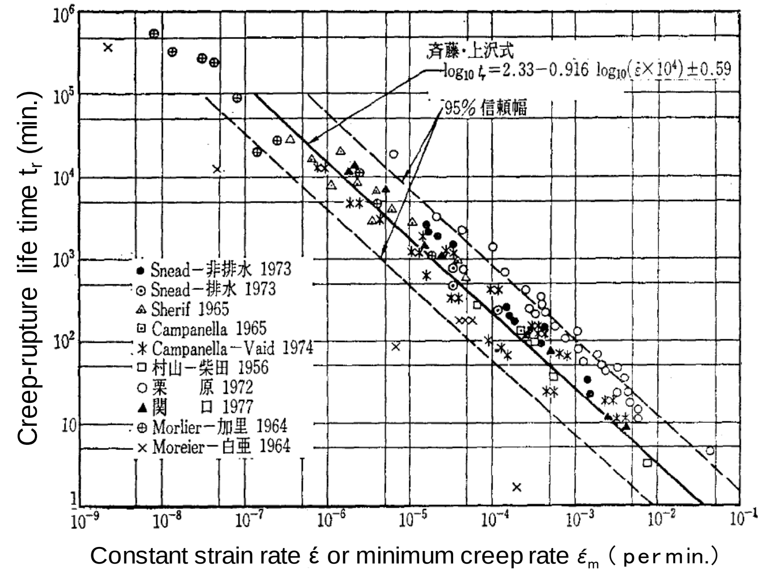
A 70m high and 200m length cut slope improvement construction works on National route 327, Miyazaki, 1990, Japan

Viewpoint from right side of opposite

Viewpoint from left side of opposite

Creep Rupture Life Prediction, from Monkman-Grant law to Saito model





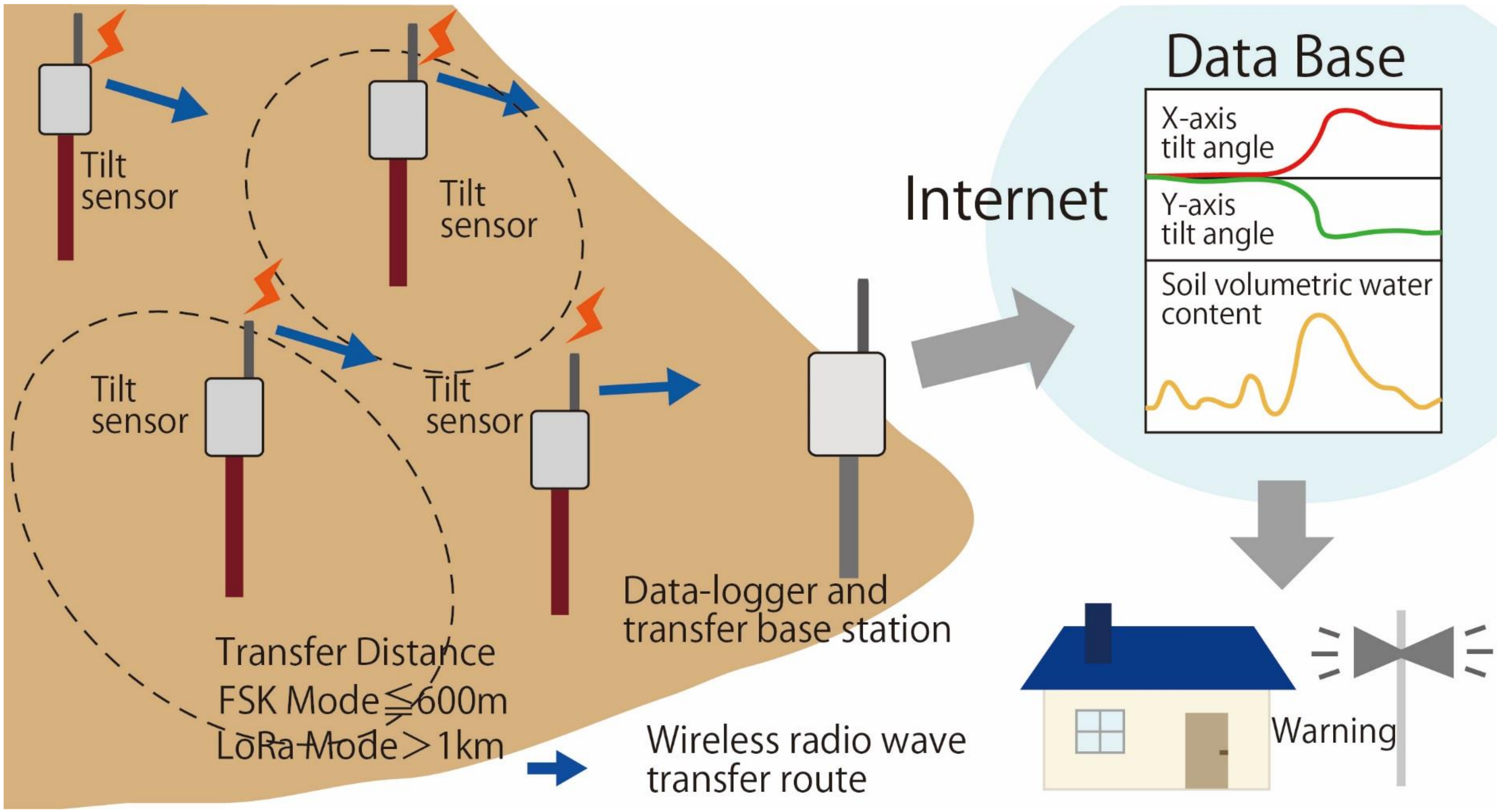
Saito finished over 80 sets tests based on Monkman-Grand law and given out

$$log_{10}t_r = 2.33 - 0.916log_{10}\left(\frac{d\varepsilon}{dt}\right)_{minimum} \pm 0.59$$

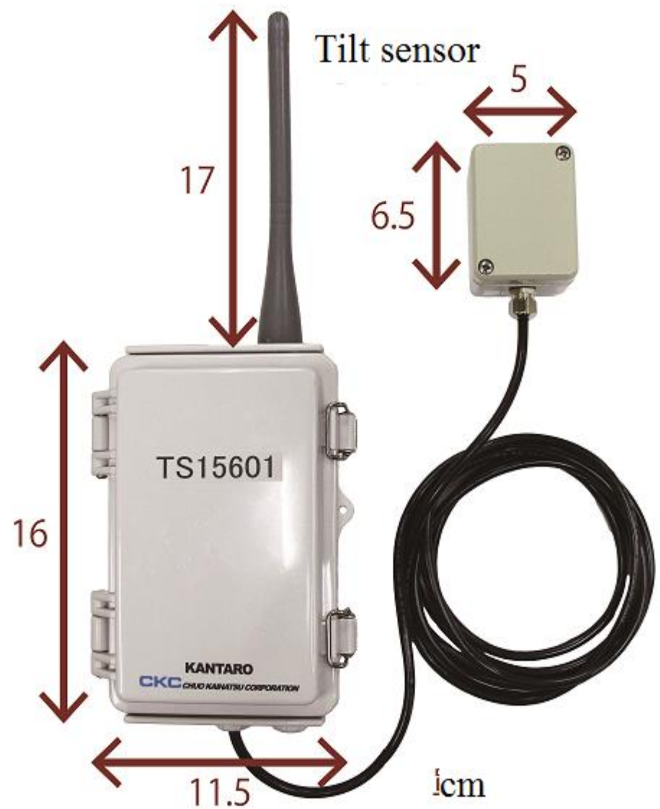
where tr is expressed in terms of minutes and the strain is expressed in terms of 10^{-4} per minute, respectively.

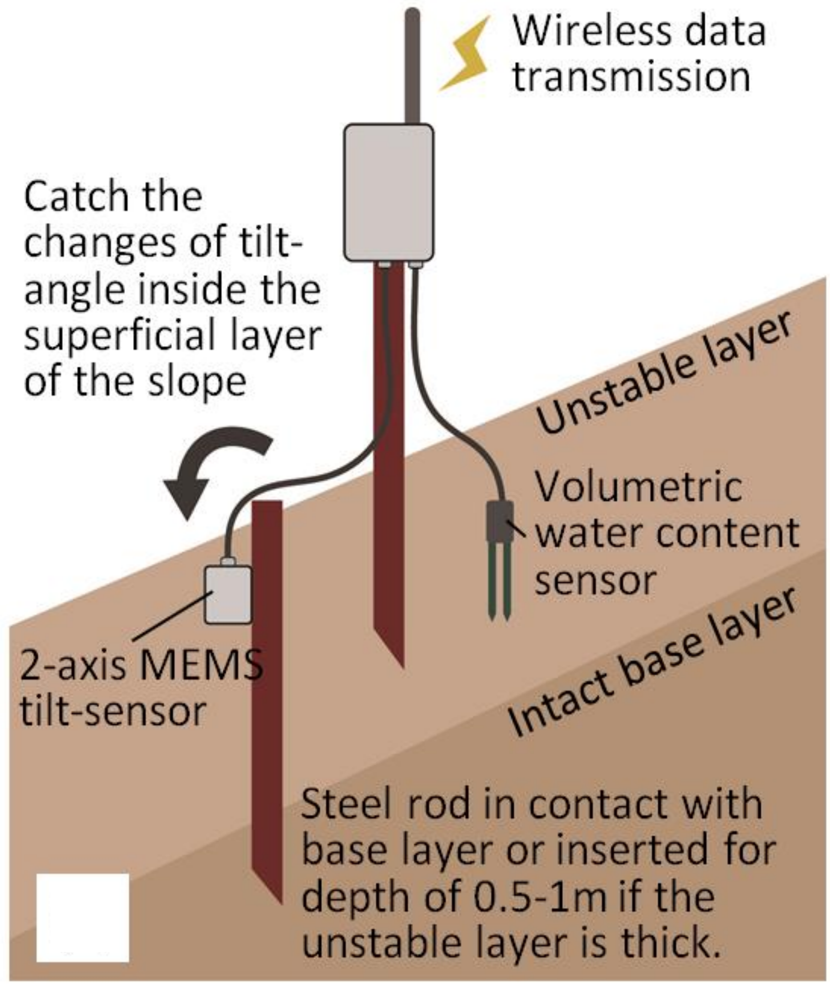
- Michitaka Saito and Hiroshi Uezawa: Failure of Soil due to creep, Proceedings of the Fifth International Conference on Soil mechanics and Foundation Engineering pp.315-318, 1961
- Saito M and Uezawa H, Failure of Soil due to creep_1961_01_0054

Slope failure monitoring tilt sensor array



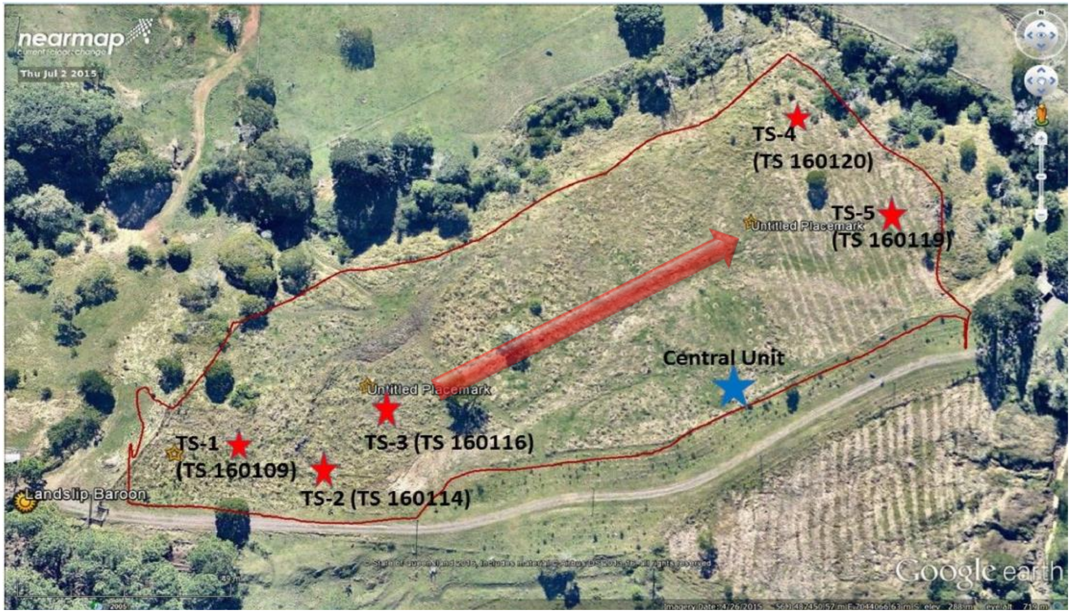
MEMS tilt sensor for monitoring of vulnerable slopes



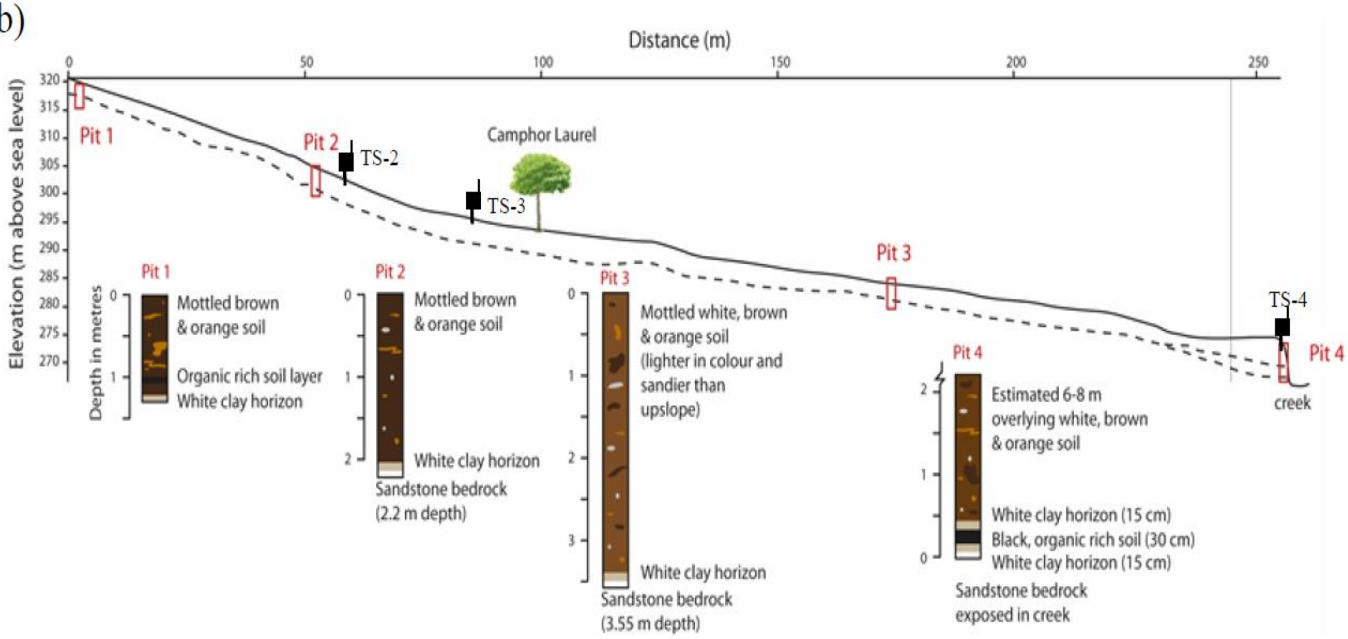


A case study of monitoring in Brisbane, Australia

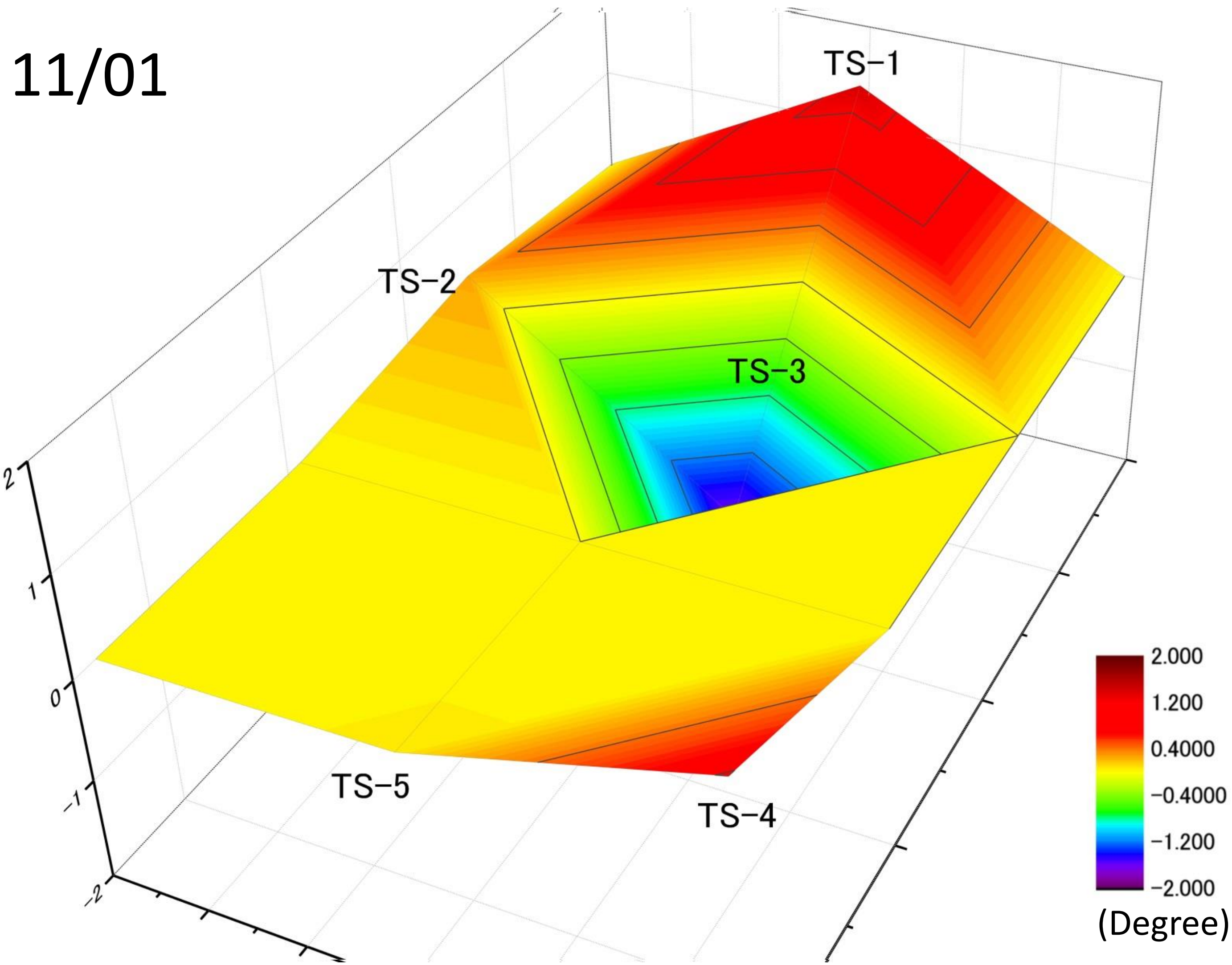
★Tilt sensor :5 sets ★Logger:1 and rain gauge : 1



(b)



The Transition of X-axis (slope direction) Tilt Angles



A case study of monitoring in Brisbane, Australia

Areal view of the landslide area (28/10/2017)

- What is the timing that we send out the warning issue based on tilt sensors array?

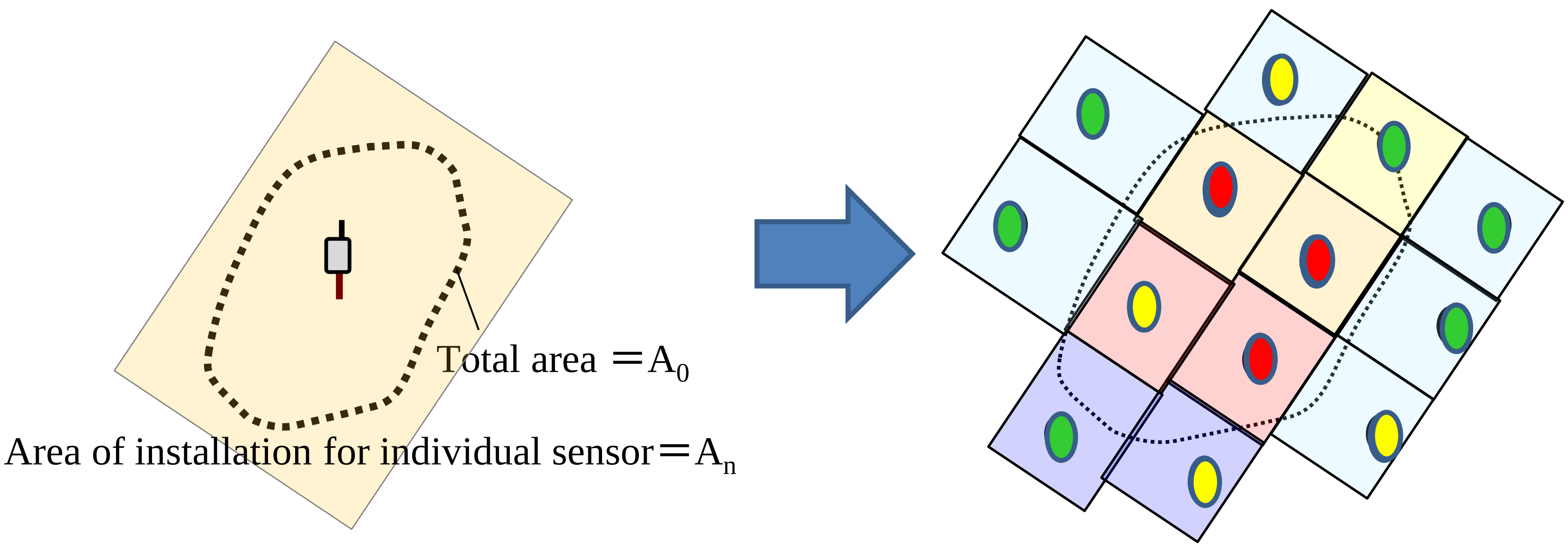
Warning threshold based on behavior of multiple sensors:

$$V_{alarm} = \sum_{n=1}^{N} \left(|V_n| \times \frac{A_n}{A_0} \times \partial_n \right)$$

V_n= Tilt rate (X-axis) of each sensor (deg./hr.), If >1.0, V_n =1.0.
A_n= Area of installation for individual sensor.
A_0= Total area of installed sensor array.
∂_n= Coefficient to be decided by the geological, soil, and vegetation conditions at installation point.

Single sensor ⇒ False warning issue can easily be caused by local movement, animal contact, etc.:

Suitable sensor intervals for multi-point measurement reduces the coverage of each sensor, thus improving system accuracy:



Conclusion:

The linear relationship between the logarithm of the rate of the tilting angle of the sensors and the logarithm of the time remaining until slope failure was demonstrated. This relationship has an interesting similarity to the relationships suggested by the Monkman-Grant model and Saito's rheological interpretation of laboratory soil tests.

The recent extension of monitoring to multi-point practice enables a more a detailed interpretation of slope behavior in the transient stage and up to the final failure.

Thank you very much for your attention !