# A study on GRP ground wave method for the variation of dune in surface soil water content in summer

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**Abstract:** The Changes in soil moisture in summer is one of the important factors that influence the state of germination and plant growth. The variation of dunes in the surface of the soil water content was measured using GPR ground wave method from May to July 2010. The results show that in this period, the water content of soil on top of the dunes is declining. It shown that during summer, the appearances of the high amount precipitation and the evaporation were the important factor in the distribution of soil water content.
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**Keywords:** GPR ground wave method; precipitation and Evaporation; soil water content

## 1 .Introduction

The plant life is always linked to water content of soil is one of the determining factors for their growth. During the summer, space is always facing to the problem of a severe shortage of water resources due to high evaporation. This period weakens the plant growth because their growths depend on soil water.

Several studies conducted in this field showed that the gravimetric method performed on the basis of soil samples is the standard method and direct that should be used to measure soil water content. However, field disturbance, labor and the inability to perform repeated measurements can be major drawbacks to the success of this method (Topp et al, 1980; 2002). Other studies have considered the reflectormetry time domain (TDR) as the most accepted method for measuring soil water content and is the most widely used (Whalley, 1993; Nielsen et al, 1995)

In several parts of the world, remote sensing methods were also used for the estimation of soil water below 0.1 m depth over a large area, with a spatial resolution that each pixel contains an actual size varies a few square meters to more than 1 $km^2$ (Huisman et al, 2003; Galagedara et al., 2005a; 2005b)

In this study, the main objective was to analyze the mane moisture content of a dune near the surface of the soil water during the drought period under study the variation of the water content in the surface VTENA

## 2. Materials and methods

### Study area

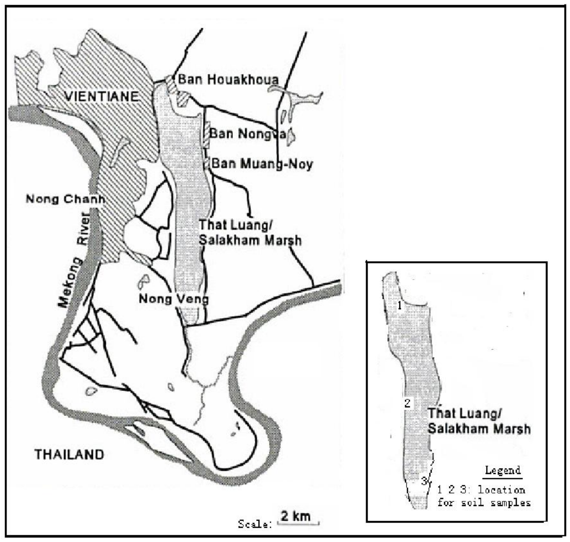


**Figure 1** mapping of Vientina salakham Marsh

The Salakham marsh (That Luang marsh) is one of the largest wetlands located in peri-urban Vientiane with an area of 68 $km^2$. Geographically, Vientiane features a tropical wet and dry climate with a distinct monsoon season and a dry season. Vientiane's dry season spans from November through March. The average rainfall is ranging between 1360mm- 1400mm. April marks the onset of the monsoons which in Vientiane lasts about seven months. Vientiane tends to be hot and humid throughout the course of the year, though temperatures in the city tend to be somewhat cooler during the dry season than the wet season.

The main activity in this valley is agriculture with 2,000 hectares under hoe cultivation. Also, Fish ponds are generally located along the margins of the marsh with an estimated of 15,000 people are involved with fishing-related activities on both commercial and subsistence levels (Coates, 2002).. Other activities are affecting the wetland's natural functions among them are: the construction a drainage canal through the swamp by the Vientiane municipality and the construction of a pumping station to remove water for paddy irrigation. The studies have shown that soil water content have also indicated that seepage of saline groundwater into the marsh may be occurring which would have a dramatic impact on the marsh ecosystem. Multiple measurements were taken to make comparisons on May 15, June 25 and July 8 in in year 2010; with the following indications about soil water content.

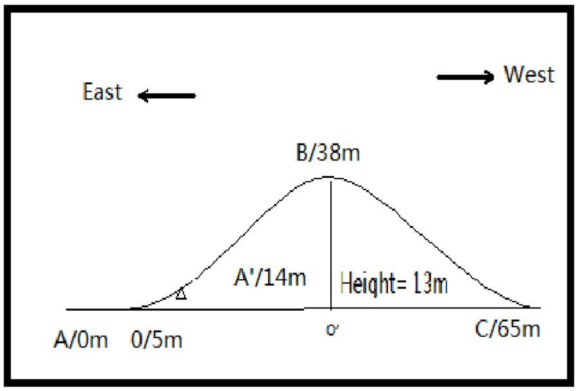


**Figure 2** A schematic diagram of the chosen dune's profile

**The GPR measurements**

For this study, GPR instruments which include a host IDS RIS-K2 multi-channel and two radar transmitter-receiver systems were used. The speed of travel of electromagnetic waves emitted by the soil depends on complex soil dielectric properties that are fundamentally determined by its water content. The water soil samplings were conducted at a time resolution of about 0.1 ns and a spatial resolution about 0.1 m. The technique is an RPG based on the ground, noninvasive geophysical survey of soil conditions instantaneously. During experience, it is shown that the transmitter produces a high frequency electromagnetic wave transmitted by the soil. Davis and Annan (1989) revealed that any basement contrast in dielectric properties reflects part of the wave energy at the surface and the reflected wave is detected by the receiving antenna as a function of time. Note that GPR derived water contents, Time-domain reflectormetry (TDR) and gravimetric method were used for verification.

The direct ground wave travel time $t_{GW}$ from the transmitter to receiver, the ground wave velocity V can be calculated as follows:

$$V = \frac{L}{t_{GW}}, \qquad (1)$$

Where

V is the ground wave velocity; L is the separation between the transmitting and receiving antenna.

The V is converted to by using the electromagnetic wave velocity in free space:

$$\varepsilon = \left(\frac{c_0}{V}\right)^2, \qquad (2)$$

Where

ε is the relative dielectric permittivity of the soil, $c_0$ is the electromagnetic wave velocity in free space.

$$t_{off} = t_{meas}^{air} - \frac{L}{c_0}, \qquad (3)$$

where $t_{meas}^{air}$ is the measured travel time of the airwave and $L/c_0$ is then correspondence to the theoretical direct airwave travel time.

$$t_{GW} = t_{meas}^{GW} - t_{off} = t_{meas}^{GW} - t_{meas}^{air} + \frac{L}{c_0}, \quad (4)$$

where $t_{meas}^{GW}$ is the measured travel time of the ground wave and $t_{GW}$ is the required absolute travel time for equation

The relationship between apparent permittivity ε and volumetric soil water content θ was calculated as follows:

$\theta = -5.3\times10^{-2} + 2.92\times10^{-2}\varepsilon - 5.5\times10^{-4}\varepsilon^2 + 4.3\times10^{-6}\varepsilon^3$ (Topp et al. (1980) (5)

This method about bulk permittivity of a soil-water-air system developed by Roth et al.(2006) and Friedman (1998), where $\varepsilon_b$, was expressed with the Complex Refractive Index Model (CRIM) as follows :

$$\varepsilon = \left[\theta\varepsilon_w^\alpha + (1-n)\varepsilon_s^\alpha + (n-\theta)\varepsilon_a^\alpha\right]^{\frac{1}{\alpha}}, \quad (6)$$

Where

n is the soil porosity; $\varepsilon_w$, $\varepsilon_s$ and $\varepsilon_a$ are the permittivity's of water, soil particles and air respectively; α is a factor accounting for the orientation of the electrical field .

The soil water content was obtained as follows:

$$\theta = \frac{\varepsilon^\alpha - (1-n)\varepsilon_s^\alpha - n\varepsilon_a^\alpha}{\varepsilon_w^\alpha - \varepsilon_a^\alpha}, \qquad (7)$$

**3. Results and Discussions**

The results detailed in Table 1 indicate the GPR profile measurements taken in summer (May to July 2010) in in peri-urban of Vientiane

Table 1 Details for GPR profile measurements in peri-urban Vientiane

| Dates | Antennas Information | | | Temperature(℃) | | Measuring | Profile |
|---|---|---|---|---|---|---|---|
| | Frequencies (MHz) | weather | Separations (m) | Soil | Air | Time* | Ends |
| 2010/5/15 | 200 | cloudy | 0.94 | 0.2 | 1.2 | 13:24 | 0-B |
| 2010/6/25 | 200 | sun | 0.82 | 0.2 | 1.52 | 16:04 | 0-B-C |
| 2010/7/8 | 200 | cloudy | 1.62 | 6.67 | 6.1 | 13:32 | 0-A-B-C |

From May to July, the Precipitations were irregulars according to the daily air temperature data obtained from the meteorological station located near to the Vientiane city.

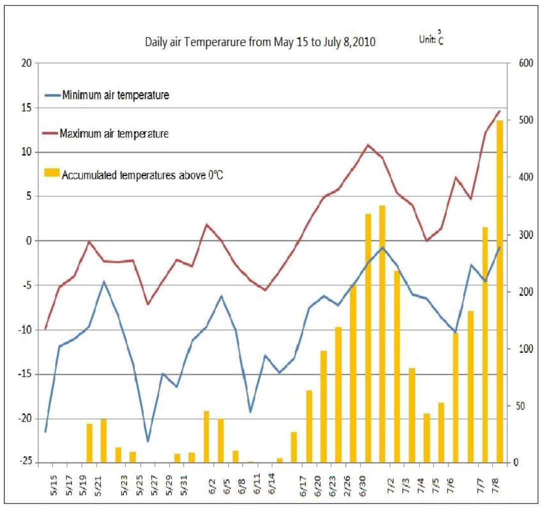


**Figure 2** The daily air temperature from May 15 to July 8 obtained from the meteorological stations in Peri-urban Vientiane

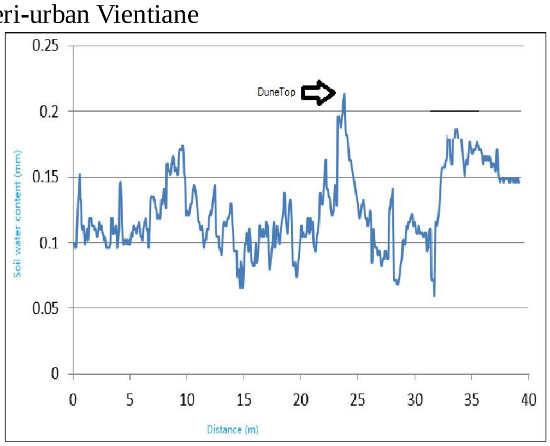


**Figure 3** The surface soil water content on June 25, 2010 in peri- urban Vientiane

The upper soil water content was about 0.1~0.15, some TDR measurements were performed to get the permittivity and water content of 0-10cm depth soil, Therefore, the TDR results were very different as indicated in Tab 2.

**Table 2** The TDR measurements on May 15, 2010

| Description | Measuring Time | Temperature for evaluation [°C] | Averaged permittivity [As/Vm] | Averaged water content [-] |
|---|---|---|---|---|
| From start of profile in one meter steps towards dune top | 9:00 | 6 | 5.89 | 0.2 |
| | 9:00 | 6 | 6.42 | 0.1 |
| | 9:00 | 6 | 9.24 | 0.126 |
| | 9:00 | 6 | 8.12 | 0.25 |
| | 9:00 | 6 | 5.03 | 0.1 |
| | 9:00 | 6 | 5.53 | 0.09 |
| | 9:00 | 6 | 6.11 | 0.063 |
| Measurements at the 2.7 m spot over 40 minutes | 15:00 | 6 | 9.32 | 0.17 |
| | 15:05 | 6 | 11.23 | 0.193 |
| | 15:40 | 6 | 8.43 | 0.13 |
| | 15:40 | 6 | 10.15 | 0.2 |
| | 15:40 | 6 | 10.25 | 0.16 |

Since the early summer from May 15 to July 15, 2010; there were changes in the soil water content in the region of Vientiane, these changes have been very clear shown through GPR image (Figure 4). Due to the length of the measure itself, the water content below included in the table 2, 3, and 4 justify the coverage of Precipitation that were almost with the same amount from May to July. The level of the evaporation was higher than that of precipitation

**Tab 3** The results of TDR measurements on June 25, 2010

| Description | Measuring Time | Temperature for evaluation [°C] | Averaged permittivity [As/Vm] | Averaged water content [-] |
|---|---|---|---|---|
| From start of profile in 1 m steps towards dune top | 11:00 | 5 | 7.2 | 0.25 |
| | 12:00 | 5 | 6.92 | 0.12 |
| | 13:00 | 5 | 5.4 | 0.43 |
| | 14:00 | 5 | 8.97 | 0.25 |
| | 15:00 | 5 | 7.6 | 0.1 |
| | 16:00 | 5 | 5.57 | 0.87 |
| | 17:00 | 5 | 7.21 | 0.5 |
| Measurements at the 1.3 m spot over 45 minutes north of the profile | 16:00 | 7 | 9.02 | 0.16 |
| | 17:00 | 7 | 11.32 | 0.193 |
| | 18:00 | 7 | 9.2 | 0.13 |
| | 19:00 | 7 | 9.56 | 0.25 |
| | 20:00 | 7 | 11.12 | 0.1 |

**Table 4** The TDR measurements on July, 8, 2010

| Description | Measuring Time | Temperature for evaluation [°C] | Averaged permittivity [As/Vm] | Averaged water content [-] |
|---|---|---|---|---|
| From start of profile in 1 m steps towards dune top | 10:00 | 9.2 | 7.11 | 0.28 |
| | 11:00 | 9.2 | 6.92 | 0.25 |
| | 12:00 | 9.2 | 5.4 | 0.1 |
| | 13:00 | 9.2 | 8.97 | 0.09 |
| | 14:00 | 9.2 | 7.6 | 0.1 |
| | 15:00 | 9.2 | 5.57 | 0.87 |
| | 16:00 | 9.2 | 7.21 | 0.5 |
| Measurements at the 13 m spot over 45 minutes north of the profile | 15:30 | 9 | 8.84 | 0.16 |
| | 16:30 | 9 | 7.394 | 0.193 |
| | 17:30 | 9 | 6.533 | 0.13 |
| | 18:30 | 9 | 9.56 | 0.25 |
| | 19:30 | 9 | 12.2 | 0.2 |

The results detailed in Table 2, 3and 4 indicate the soil situation at depth of 0~20 cm and 0~10 cm respectively. It showed a lower value means water content of soil layer at depth 0~10 cm lower than the soil layer at depth10~20 cm . This situation may be due to the evaporation that could me higher than precipitation.

From May to July 2010, the precipitations were estimated between 0.6-0.8 mm in this Region, that may have big impact to the soil water content ;the evaporation was high than precipitation and the decrease of soil water content was observed as indicated in table 2, 3 and 4 that describe the declining of soil water contents.

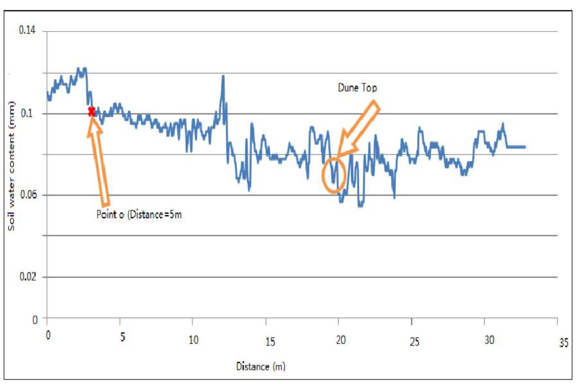


**Figure 4** The soil water content calculated by Ground Wave Method on summer, 2010 at Vientiane

For a better demonstration and good understanding of the situation of subsurface conditions, one vertical soil profile was dug on the dune top and near the GPR profile on May15, and two vertical soil profiles were dug on the dune top and the flat dune base respectively on June and July. The results show that in this period, the water content of soil on top of the dunes is declining and this has big impact on soil water content in peri-urban of Vientiane.

## 4 Conclusions

This study was conducted with the main purpose of analyzing the water content of soil in the peri-urban of Vientiane. The results obtained using the GPR measurements showed lower content of soil water content in this area. It was shown that the soil water content decreased over time, consistently since the month of May until July. The sunshine and evaporation are the major factors that influence the amount of water content during the summer because the rapid acquisition of changes on the surface soil moisture is of great importance. This shall mean that the precipitation and evaporation are not balanced to maintain the stability of the water contained in the soil.

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