Detection of Cropland Salinization with Vegetation Index In Various Coastal Condition

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Abstract. Salinization of soil and water greatly bring negative impact on the productivity of agricultural land which is located in coastal areas. Traditionally, predictions of salinity in soil and water can be done by field studies and samples monitoring. The development of Remote Sensing (RS) makes the salinity can be studied quantitatively through multi-temporal and multi-spectral information. This study aims to detect and segment area affected by salinization using correlation test of Landsat 8 satellite imagery and field measurement data. Satellite imagery is processed for various Vegetation Indices. Data on water and soil salinity are collected from field measurement. The correlation between Vegetation Index with soil and water characteristics is tested by correlation analysis. The result shows that there is a good enough correlation between VI with TDS, Mg/Ca, Cl/HCO₃ and low correlation between VI with water EC and salt content. Area nearer to sea tends to have higher salinity and lower VI. There is no correlation between VI with groundwater EC and soil EC.

Keywords: salinization, vegetation index, cropland

1. Introduction
The term salinization is used to describe the process and impact of salt and water, including the measurement of salt content in soil or water [1]. Soil salinity is the accumulation of salt dissolved in soil [2]. Salt accumulation can happen naturally (primary salinity) or by human activities (secondary salinity). Human activities, such as land clearing, irrigation, and morphological landscape change, could be interference salt content in the soil layer, especially upper layer or topsoil. It will change the movement and accumulation of the salt content cause hydrological cyclic [1,3]. Salinization on soil assessment needs the understanding of groundwater movement characteristics because it controls salt mobility and transfers among other factors [4].

According to Hillel [5], soil salinity is an environmental hazard which can affect vegetation growth. Although salinization may not inflict damage as dramatically as earthquake or landslide, it can decrease agricultural production [3, 6]. Salinization brings additional negative effect, like soil property devaluation, land degradation, river eutrophication, infrastructure damage, and increasing soil erosion [7].

It is modeled that about one billion hectare, which equals to 7% of earth surface area, has salinization[8]. According to FAO in 2016, for 230 million ha of available irrigated agricultural land, 45 million (19%) of it is affected by salinity. Most of the affected area is caused by human activities,
especially, in irrigation area[7]. Abbas et al. [9] predicts that in soil salinization reaches 2 million ha annually in a global scale.

Soil salinization often causes the declining of paddy harvest and the decreasing of soil quality to be not arable. Agricultural land in the coastal area which has irrigation along the year has a high risk of salinization. Temporal monitoring of soil and water salinization in the coastal area is needed in order to keep the negative impact remaining tolerable. The use of Landsat 8 satellite which has a dynamic spatial and temporal resolution can be the solution of efficient cost to monitor salinization in the coastal area [6].

This study aims to detect and segment area affected by salinization using Landsat 8 satellite imagery. The affected area is segmented with vegetation indices of NDVI, SAVI, and EVI. Vegetation indices from satellite imagery are tested the correlation with river water electric conductivity (EC), salinity, Mg/Ca, Cl/HCO₃, groundwater EC, and soil EC from field data and laboratory data.

2. The Methods

2.1. Study Area

![Study area at Bonang (up left), Temon (upright), and Kaliori (down) Subdistrict Source: Landsat 8 OLI Satellite Imagery.](image)

There are 3 study areas in this research. The first study area is located around Tuntang River in Demak District, Middle Java Province. There was several indications of salinization by intrusion over the river Tuntang. By different season, paddy field was affected by seawater intrusion in irrigation system of river Tuntang. Seawater salt intrusion in dry season into Demak District reaches more than 4 km in Demangan River and more than 7 km in Tuntang River[10]. Sea water intrusion is intensive in Demak coastal area because of the plain morphology formed from alluvial deposition[11].
The second study area is at Temon Subdistrict, Kulonprogo District. Most residents in the area use groundwater from well. Saline groundwater mostly found near coastal included agriculture land area. This makes it a good place to research the correlation between groundwater salinity and salinization in agriculture land.

The other study area is at Kaliori Subdistrict, Rembang District. There are not many residents using groundwater there. The river is not affected by seawater intrusion. However, the place has good accessibility to the cropland so that the soil sample can be collected easily.

2.2. Materials and Data
The materials and data used to support the research are listed in Table 1.

| Num | Materials and Data | Function |
|-----|--------------------|----------|
| 1   | Peta RBI (RupaBumi Indonesia) of scale 1:25.000 | To map landuse and other basic spatial data |
| 2   | Geologic Map of scale 1:100.000 | To know the lithology |
| 3   | Hydrogeologic Map of scale 1: 100.000 | To know the aquifer potential |
| 4   | Semi Detail Soil Map of scale 1:25.000 | To know the soil distribution |
| 5   | Landsat 8 OLI | To analyze Vegetation Indices |
| 6   | Water EC, TDS, salt content, Mg, Ca, Cl, HCO₃⁻ | To analyze river water salinity |
| 7   | Groundwater salinity | To analyze groundwater salinity |
| 8   | Soil EC | To analyze soil salinity |

The following Table 2 contains tools used in the research.

| Num | Tools | Function |
|-----|-------|----------|
| A. Field Survey Tools |
| 1   | GPS | To plot location coordinate |
| 2   | Water checker | To measure the water EC, TDS, and salt content |
| 3   | Sample bottle | To sample the water |
| 4   | Auger hole | To sample the soil |
| 5   | Camera | To capture pictures in fieldwork |
| B. Laboratory Tools |
| 6   | Laboratory Tools to analyze water and soil chemistry | To analyze the water and soil chemistry |
| 7   | GIS software: ArcMap, ENVI 4.3 | To process satellite imagery and field data in order to create maps |
| 8   | Statistics software: SPSS 16 | To analyze statistically |

2.3. Satellite Imagery and Data Preparation
Choosing Landsat 8 satellite imagery to segment cropland salinity is according to cultivating pattern which is before harvesting period. Geometric and radiometric correction to decrease noise and backscattering is processed with ENVI software. Field sampling is decided based on distance and land cover for each segment. The Landsat 8 imagery date used is suited near with fieldwork date. River water and groundwater EC is measured directly in the field using water checker. River water is sampled with a sample bottle to analyze in the laboratory. Topsoil is sampled using the auger hole and the EC is analysed using not saturated technic. Each sample location coordinate is recorded by GPS.
2.4. **Indirect Indicator Parameter**

The method of segmentation using Landsat 8 Imagery is a Vegetation Index. Vegetation Index (VI) is a popular method and proven in monitoring vegetative biomass and condition [12]. VIs have been succeeded to use for soil salinity mapping with Normalized Difference Vegetation Index (NDVI) [13-15], Soil-adjusted Vegetation Index (SAVI) [14, 16-18] and Enhanced Vegetation Index (EVI)[19]. NDVI is defined as:

\[
NDVI = \frac{(N-R)}{(N+R)}
\]

where N is reflectance of Near Infrared (NIR) band and R is reflectance of the Red band.

The drawback of NDVI is it is very sensitive to soil brightness [20]. Therefore, Huete [20] uses Soil-adjusted Vegetation Index (SAVI) which has soil adjustment factor (L). SAVI is defined as:

\[
SAVI = (1 + L) \frac{(N-R)}{(N+R+L)}
\]

Soil adjustment factor (L) varies from 0 to 1 depending on the soil seen. The low L value means vegetation covers increase and a little soil is seen. The value 0.5 of L is used if the area of soil seen is not known [17]. SAVI gives a better result that NDVI does in low vegetation cover because it reduces soil noise effect [17].

Enhanced Vegetation Index (EVI) is developed to optimize vegetation signal with sensitivity in high biomass area. This also improves vegetation monitoring by erasing canopy background and reduces atmosphere effect. EVI is defined as:

\[
EVI = G \frac{(N-R)}{(N+(C_1+R)-(C_2+B)+L)}
\]

where G is factor index (2.5), C_1 and C_2 are aerosol coefficients, and B is blue band reflectance.

2.5. **Water Salinity Level**

River water and groundwater salinity are described by measuring the EC as shown in table 3. Darmanto and Cahyadi[10] use the classification to describe river water salinity. Widada[21] uses it to describe groundwater salinity.

| Water EC (µS/cm) | Description       |
|-----------------|-------------------|
| <1.500          | Freshwater        |
| 1.500-5.000     | Slightly brackish water |
| 5.000-15.000    | Brackish water    |
| 15.000-50.000   | Salty water       |
| >50.000         | Brine water       |

Source: Widada[21]; Suherman in Darmanto and Cahyadi[10]

2.6. **Soil Salinity Level**

| EC Value (mS/cm) | Effect                                      |
|-----------------|---------------------------------------------|
| 0-2             | Salinity effect is neglected                |
| 2-4             | Sensitive crop productivity can be restrained|
| 4-8             | Many kinds of crop productivity are highly restrained |
| 8-16            | Only insensitive kinds of the crop can be harvested impressively |
| >16             | A few of insensitive crop can be harvested impressively |

Source: Notohadiprawiro [22]
Notohadiprawiro [22] assessed paddy productivity according to salt content in soil with soil electric conductivity (EC). Table 4 shows soil salinity level effect according to EC in mS/cm unit in 25°C. Poerwowidodo [23] classifies soil EC according to salt content level. Hanson et al. [24] states that soil salinity tolerance of crop is also influenced by coast morphology or slope.

Table 5. Soil salinity level according to soil EC.

| EC Value (mS/cm) | Soil Salinity       |
|------------------|---------------------|
| 0-2              | Not saline          |
| 2-4              | Less saline         |
| 4-8              | Slightly saline     |
| 8-15             | Moderately saline   |
| >15              | Highly saline       |

Source: Poerwowidodo (2002) [23]

2.7. Model Analysis

Land cover is mapped from Indonesia (RBI) and field survey. Non-agricultural land is not calculated in imagery processing. This means to reduce the range of NIR spectral and increase the range of reflectance which response to salinity impact of vegetation [14]. Soil EC, water EC, Total Dissolved Solid (TDS), water salinity, Mg/Ca, and Cl/HCO₃ values obtained in the field survey will be compared with each VI.

Regression analysis tests the statistical correlation between VI indirect parameters and soil EC, water salinity, Mg/Ca, and Cl/HCO₃. The regression model is done with stepwise linear regression and partial least square regression using SPSS software. VI indirect indicators are the independent variables while soil EC, water EC, TDS water salinity, Mg/Ca, and Cl/HCO₃ values are the dependent variables.

3. Result and Discussion

3.1. Tuntang River Water Correlation with VIs at Bonang and Demak Subdistrict, Demak District

The study area of Tuntang River is located in Bonang Subdistrict and Demak Subdistrict, Demak District. Tuntang River flows among Salatiga City, Semarang District, and Demak District. The spring of Tuntang River is in the north of Merbabu Mountain. Tuntang River flows in the south of Ungaran Mountain and north and east of Telomoyo Mountain. Water from Pening Swamp is the input of Tuntang River which then flows to northeast, northwest, and finally enters the Java Sea. The river water is used for the hydroelectric power plant and regional drinking company to supply fresh water.

Sample location is selected based on distance from the nearest sluice gate toward the coast. The river is segmented for every 1 km with the sample location for every 1 km. There are 7 sample locations in total with point A, the farthest from the pond and sea, until point G, the nearest to the pond sea.

Results of VIs analysis for NDVI, SAVI, and EVI are shown in figure 3. NDVI value of -1 to -0.32 means that there is no vegetation, but water or covered by cloud. Value -0.32 to 0.32 is classified as low-density vegetation usually in bare land, settlement, buildings, and industries. The slight density of vegetation with land-use of dry land and grass has VI value from 0.32 to 0.55. Moderate vegetation density has VI ranging from 0.55 to 0.78 which indicates plantation, dry cropland, and bush. Forest with high vegetation density has a VI value of 0.78 until 1.00 [25]. In the map of VI, the negative value of NDVI indicates the lands of pond and settlement land. The positive value indicates vegetation with a certain density.

Landsat 8 imagery spatial resolution has 30 x 30 meter for every pixel, while river water sample is collected in point site. Hence, the VI value of each point of sample location is the composite of cropland VI within the radius of 500 meters. This is to obtain the VI composite value of vegetation around the sample location which is affected by Tuntang River water salinization.
Figure 2. Some sampling conditions at point B (left), C (middle), and D (right).

Figure 3. The result of NDVI (up left), SAVI (up right), and EVI (down left) classification at Kaliori Subdistrict, Demak District. Source: Data processing, 2017. Source: Tivianton et al. [26]
Table 6 shows every sample location along Tuntang River with VI composite value of cropland around it. Each method of NDVI, SAVI, and EVI shows the same pattern. Generally, VI tends to be high at point A and drops gradually to point G, nearer to the sea. IV value at point G, the nearest to the pond, is the lowest. This suggests that vegetation density tends to fall toward the pond. Vegetation density and biomass decline drastically at point F and G.

| Point | TDS (ppm) | Salt Content (ppt) | EC (µS/cm) | Salinity       | NDVI  | SAVI  | EVI  |
|-------|-----------|--------------------|------------|----------------|-------|-------|------|
| A     | 411       | 412                | 840        | Not saline     | 0.761 | 0.560 | 1.041|
| B     | 542       | 375                | 789        | Not saline     | 0.501 | 0.309 | 0.548|
| D     | 512       | 359                | 735        | Not saline     | 0.727 | 0.522 | 0.968|
| E     | 519       | 364                | 749        | Not saline     | 0.624 | 0.406 | 0.747|
| F     | 485       | 337                | 689        | Not saline     | 0.477 | 0.271 | 0.480|
| G     | 778       | 544                | 1109       | Not saline     | 0.480 | 0.260 | 0.462|

Source: Field data measurement and Landsat 8 imagery processing in Tivianton et al. [26]

The result of VI calculation is compared with Tuntang River water quality. The river water quality data collected consists of water EC, TDS, water salinity, Mg/Ca, and Cl/HCO₃. Water EC, TDS, water salinity, and pH data are measured directly in the field survey. The Calcium, Magnesium, Chloride, and Bicarbonate ion contents are analyzed in the laboratory.

The result shows that water EC along the river respectively is 840 µS/cm, 789 µS/cm, 735 µS/cm, 749 µS/cm, 689 µS/cm, and 1109 µS/cm (table 6). River water in point C cannot be measured because it is buried (figure 2). According to the classification of Suherman in Darmanto and Cahyadi [10], the river water is categorized as fresh water based on the water samples. The highest salinity is found at point G with water EC value of 1109 µS/cm. This makes sense as the point G is the nearest to the pond land.

Salinization effect or sea salt accumulation in the soil can happen naturally or by human activities. The natural factors are the effect of lithology material of marine sediment that contains high salt causing water salinity and seawater intrusion into the coastal area through river body. Tuntang River is affected by seawater intrusion according to its water EC value. Darmanto and Cahyadi [10] suggest that the water EC reaches 5 500 micro mS/cm until above 20 000 µS/cm. However, this condition has changed sharply since the sluice gate construction in the pond. It minimalizes sea water intrusion effect into the river body.

The salinization cropland around Tuntang River in the coastal area is mostly the consequence of marine deposition lithology. Ion contents of Calcium (Ca), Magnesium (Mg), Chloride (Cl), and Bicarbonate (HCO₃) of the river water are tested. The ionic ratio of Mg/Ca and Cl/HCO₃ can show the cause of the salinization [27]. Point A until F has low Mg/Ca and low Cl/HCO₃ which means that the salinization derives from carbonate aquifer of marine deposition. Point G has a higher ratio of Mg/Ca and Cl/HCO₃ indicates that seawater intrusion brings more salinization effect.

Correlation test of field data and VI is done to assess the effect of salinization at cropland Tuntang River. Correlation test shows the relation between each of water EC, TDS, salinity, Mg/Ca ratio, and Cl/HCO₃ and each of the VI. Every correlation test has the significance of 0.05. Correlation between water EC and VI is very low, which is below 30% and a negative value (table 8). Correlation between salinity and VI is not far different. The correlation is less than 30%. The inverse correlation means that the higher water EC is, the lower VI is. Biomass which indicated with vegetation density and VI declines as the water EC rises. The low correlation (<30%) may be caused by lacking representative data.
Table 7. The result of laboratory analysis of Tuntang River water.

| Point | Ca (ppm) | Mg (ppm) | Mg/Ca | Cl (ppm) | HCO₃⁻ (ppm) | Cl/HCO₃⁻ |
|-------|----------|----------|-------|----------|------------|----------|
| A     | 60       | 15       | 0.250 | 126      | 312        | 0.404    |
| B     | 62       | 18       | 0.290 | 122      | 292        | 0.418    |
| D     | 58       | 15       | 0.259 | 114      | 260        | 0.438    |
| E     | 56       | 15       | 0.268 | 118      | 236        | 0.500    |
| F     | 54       | 16       | 0.296 | 106      | 248        | 0.427    |
| G     | 54       | 23       | 0.426 | 204      | 328        | 0.622    |

Source: laboratory analysis (2016)

Table 8. Correlation test of variables TDS, Mg/Ca, Cl/HCO₃⁻ with each VI.

| Pearson Correlation | NDVI | SAVI  | EVI  |
|---------------------|------|-------|------|
| EC                  | -0.258 | -0.291 | -0.285 |
| Salt content        | -0.234 | -0.270 | -0.263 |
| TDS                 | -0.588 | -0.627 | -0.620 |
| Mg/Ca               | -0.666 | -0.701 | -0.695 |
| Cl/HCO₃⁻            | -0.414 | -0.477 | -0.465 |

Source: laboratory analysis (2016)

The test shows that there is good enough correlation between TDS of river water and VI, with the value of 58.8% to 62.0%. Correlation between hydrochemistry and VI is also good enough. The correlation between Mg/Ca and VI ranges from 66.6% to 70.1% and between Cl/HCO₃⁻ and VI is 41.4% to 47.7%. The highest correlation between Mg/Ca and VI means that water salinity interpreted with VI tends to be affected by saline groundwater mixing into the river. Among the 3 VIs, SAVI shows the highest correlation value with every variable from field data. SAVI can be suggested as the best VI to detect water salinity, especially caused by TDS, Mg/Ca, Cl/HCO₃⁻.

3.2. Groundwater Salinity correlation with VIs at Temon, Kulonprogo

Figure 4 shows the result of VI calculation at Temon Subdistrict, Kulonprogo District. In general, it looks like there are 4 layers stretching parallel to the shoreline from southwest to northeast. The first layer, located the nearest from the sea, has lower VI. The landscape there is a beach and sand dune with land-use of grass. The second layer has a higher VI because it is mostly plantation. At the north of the plantation it is cropland with lower VI. The last layer at the northeast part of the study area has higher VI as it is also mostly plantation area.

Groundwater EC distribution at Temon Subdistrict is shown in figure 5. In average, the groundwater EC ranges from 200 µS/cm to 800 µS/cm. Most of the groundwater EC samples are below 1 500 µS/cm which means that most of the groundwater is fresh water. The Brackish groundwater, with EC of 2 000 µS/cm, is found only at a limited area at the east part of the study area.

Groundwater EC samples are taken as much as 80 samples from [28]. Each of samples is located at a place of which the VI is taken and then tested with groundwater EC. The correlation test will check the relation between groundwater EC and VI.

Correlation test shows that there is no correlation between groundwater EC and VI. The correlation is below 20% and in a positive value. If the saline groundwater made vegetation biomass lower, the correlation should be in negative value. Brackish groundwater area does not influence VI to be lower.
Although the groundwater is brackish, it does not bring salinization to the soil and make the vegetation biomass lower.

**Figure 4.** Map of NDVI (up left), SAVI (up right), and (down left) at Temon Subdistrict, Kulonprogo District.

**Figure 5.** Map of groundwater EC distribution at Temon Subdistrict, Kulonprogo District. Source: Santosa [28]
**Table 9.** Correlation test between groundwater EC and VIs.

| VIs | Correlation |
|-----|-------------|
| NDVI | 0.194 |
| SAVI | 0.110 |
| EVI | 0.034 |

Source: Data processing (2017)

3.3. **Soil Salinity correlation with VIs at Kaliori, Rembang**

NDVI, SAVI, and EVI imagery process result at Kaliori Subdistrict are shown in figure 6. In general, VI in the study area is lower at the west part of Kaliori Subdistrict and higher at the middle and east parts. In other words, vegetation density and biomass at the west part is lower than the middle and east part. The lowest vegetation density is located along the border separating pond and farmland. It stretches from east to west.

The soil sample is collected at point T1 to T13 in order to test the soil EC and soil salinity. Table 9 shows soil EC and soil salinity with each VIs. The VI values derive from the Landsat 8 pixel where the soil samples are taken. According to the classification of Notohadiprawiro [22], soil salinity does not affect the vegetation biomass. Poerwowidodo [23] explains that the low soil EC or salinity is classified as not saline so that it has no effect to vegetation biomass.

Table 11 shows the correlation between both soil EC and soil salinity and VI. The correlation values are barely the same because soil salinity calculation derives from the soil EC. Soil EC and soil salinity have low correlation with the three VIs, which are below 17%. In addition, the correlation value is positive, not negative. If the soil EC and salinity affected the vegetation biomass, higher VI must be followed by lower soil EC and salinity. That this trend does not appear means vegetation biomass at Kaliori Subdistrict is not affected by soil EC and salinity. The variation of vegetation density in the study area is the result of other factors. Soil EC and salinity are not the main factors because the tropical area has high rainfall so that the salt content is lower than subtropical area.

Some experiments in detecting soil salinity using VIs are successful, for example in the Vaalharts Irrigation Scheme and the Breede River in South Africa [29] and Yellow Delta River in China [14]. Detecting soil salinity with VIs of remote sensing is without complication. Plant species with high tolerance of salt can result in ambiguity in VI response [30]. Bad cropland preparation and agricultural work can make the stressed vegetation wrongly interpreted as affected by salinity [31].

**Table 10.** Soil EC and soil salinity with each VI.

| Code | Soil EC (µS/cm) | Soil Salinity (%) | Salt Content in Soil | VIs | NDVI | SAVI | EVI |
|------|----------------|-------------------|---------------------|-----|------|------|------|
| T1   | 250,4          | 0,037             | not saline          |     | 0,558| 0,295| 0,477|
| T2   | 192,0          | 0,031             | not saline          |     | 0,508| 0,248| 0,383|
| T3   | 202,1          | 0,032             | not saline          |     | 0,578| 0,261| 0,433|
| T4   | 453,7          | 0,059             | not saline          |     | 0,715| 0,387| 0,616|
| T5   | 99,8           | 0,021             | not saline          |     | 0,640| 0,349| 0,587|
| T6   | 61,2           | 0,017             | not saline          |     | 0,672| 0,348| 0,540|
| T7   | 85,0           | 0,019             | not saline          |     | 0,714| 0,334| 0,551|
| T8   | 147,4          | 0,026             | not saline          |     | 0,605| 0,299| 0,458|
| T9   | 162,4          | 0,028             | not saline          |     | 0,671| 0,374| 0,598|
| T10  | 119,1          | 0,023             | not saline          |     | 0,536| 0,290| 0,450|
| T11  | 88,7           | 0,020             | not saline          |     | 0,624| 0,356| 0,588|
| Code | Soil EC (µS/cm) | Soil Salinity (%) | Salt Content in Soil | VIs | NDVI | SAVI | EVI |
|------|-----------------|-------------------|---------------------|-----|------|------|-----|
| T12  | 99,5            | 0,021             | not saline          |     | 0,533| 0,218| 0,344|
| T13  | 66,8            | 0,017             | not saline          |     | 0,603| 0,335| 0,555|

Source: Data processing (2017)

Figure 6. Map of NDVI (up left), SAVI (upright), and (down left) at Kaliori Subdistrict, Rembang District.

Table 11. Correlation between soil EC-salinity and VI.

| Pearson Correlation | NDVI | SAVI | EVI |
|---------------------|------|------|-----|
| Soil EC salinity    | 0,154| 0,163| 0,121|
|                     | 0,153| 0,164| 0,121|

Source: Data processing (2017)
4. Conclusion
Tuntang River water has low salinity and classified as fresh water. The highest salinity locates at point G, which is the nearest to the pond. VI at point A is the highest and tends to drop as it gets nearer to the pond, at point G. VI reaches the lowest value at point G. It means that vegetation density falls as it gets nearer to the pond. Correlation test shows that there is a good enough correlation between VI and TDS, Mg/Ca, Cl/HCO₃ and low correlation between VI with water EC and salt content. The low correlation is because of the lacking representative sample.

The groundwater EC which reflects the salinity does not correlate with VI at Temon Subdistrict, Kulonprogo District. Most of the groundwater is fresh water. There is an only limited area of which the groundwater is brackish at the east of the study area. The variation of VI is not affected by groundwater EC, but it is according to the land-use.

The soil salinity does not correlate with VI at Kaliori Subdistrict, Rembang District. All of the soil salinity samples are classified as not saline. The VI is lower at the west part and higher at the east part. Different VI of cropland which reflects vegetation biomass at the study area is not the effect of soil salinity.

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