

Investigation the Impact of Land Surface Temperature on Type of Land Use

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Abstract: Rapid Land use changes in Netherlands especially in urban expansion and open agriculture reduction which are due to enhanced economic growth. This research was investigated the impact of land surface temperature on type of land use in Netherlands using remote sensing, geographic information systems (GIS) and statistical methods. As land use change alters the thermal environment, LST could be a proper change indicator to show thermal changes in relation to land use changes. GIS was further applied to extract the coverage ratio of each land use in the context of LST pixels. Using correlation and linear regression this interrelationship was then quantified. Overall, the key results confirm that Build-up area and open agriculture has the largest LST difference between day and night values. Inland water has the maximum night LST, minimum day LST and the minimum LST difference between day and night.

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1. Introduction

NASA launched the Earth Observing System's flagship satellite "Terra" on December 18, 1999. Terra has a sun-synchronous, near polar, circular orbit which passes the earth from north to south. It crosses the equator in the morning (10:30 a.m.) and visits the entire Earth's surface each 1 to 2 days. Terra carries five sensors including ASTER, CERES, MISR, MOPITT and MODIS (NASA, 2012).

In this study data derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) product is used. MODIS has a 36 spectral band spectrometer. MODIS thermal infrared (TIR) bands are used for LST retrieval. Land surface temperature (LST) is temperature of the skin surface of land which can be derived from satellite information or direct measurements. In the remote-sensing terminology LST is the surface radiometric temperature emitted by the land surfaces and observed by sensor at instant viewing angles (Prata et al., 1995). Land use is defined as "the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it" (FAO/UNEP, 1999). Different land use type have different amount of land surface temperature during day and night times. This study investigate the night and day LST values for different land use types.

Methodology

The Netherlands is a country in Western Europe which borders the North Sea to the north and west, Belgium to the south and Germany to the east.

The spatial land use database of Statistics Netherlands (NL: BBG, Bestand Bodemgebruik), is a frequently updated dataset of land use information in the Netherlands which was used for this research. BBG is used for this study. The satellite data used for this study were MODIS LSTs, and the product was the 8-day 1 km MOD11A2, averaging LSTs in the daily product MOD11A1 over 8 days. The 8-day composites of these LST HDF images were downloaded for the period from 2000 to 2008. LST values per pixel were extracted from Oklahoma website available at: <http://www.eomf.ou.edu/visualization/gmap/>.

To retrieve LST values, MODIS pixel locations were entered based on the geographic coordinates (Latitude and Longitude). For each pixel, LST values were retrieved from 2000 to 2008 with 8-day intervals and in ASCII Table format. The raw LST values were multiplied by the scale factor of 0.02. The scale factor was defined in the LST product user manual (Zhengming, 2007). Afterwards, the LST values were subtracted by 273.15 to be converted from Kelvin to degrees Celsius. Multiple land uses can be present in one 1-km² LST pixel and each of the land use classes can affect the LST mixed value. The coverage ratios of different land use types within individual MODIS pixels was computed. The land use types are open agriculture, build-up area, recreational area, greenhouse farming, forest and inland waterway & offshore area.

To examine weather different land uses have different LST values, and to see if there is any change of LST values through time (from 2000 to 2008), 27

representative cells were selected. These cells had fixed land use from 2000 to 2008. The representative cells were including of all land uses. Each land use had 5 cells apart from recreation areas that were represented by 2 cells. For the recreation class 5 pixels were not available. Representative cells had even distribution in the whole Netherlands. The temporal pattern of LST was analyzed with time plots which showed how LST behaves through time. After quality assessment and rejecting poor pixels, the temporal behavior of LST was plotted for single location pixels. LST values were extracted for every single representative cell from 2000 to 2008. Using SPSS 17 (SPSS Inc, 2008) and a one-way ANOVA function, Analysis of variance was tested. The ANOVA was used to test the hypothesis that several means of different land use classes are equal.

In addition to determining if differences exist among the means, post hoc tests were applied to see which means that were differing, and where the difference among the means lie. The ANOVA results were analyzed using the Bonferroni post hoc test (Newsom, 2006). The Bonferroni is possibly the most frequently used post hoc test, because it is very flexible and simple to compute (Newsom, 2006).

Result and discussion

NOVA test for day time LST

ANOVA is a statistical method used to compare the means of two or more groups. Tab.1 shows the descriptive analysis of night LST values of 27 fixed land use pixels. The column called count is the number of LST values extracted from fixed land use pixels from 2000 to 2008. For example, in five pixels with entirely open agriculture land use from 2000 to 2008, 1498 LST values are extracted. The column sum is the sum of all night LST values for each land use. Dividing the sum columns by the number of involved pixels, arithmetic mean is computed. The lowest mean LST is observed in forest, followed by open agriculture, recreational area, greenhouse farming, build-up area and inland waterway and offshore area.

The warmest land use during the nights is Inland waterway and offshore area. Water has an extremely high heat capacity J/kg/°C (Sharp, 2001); this means that water can absorb a lot of energy before it increases temperature. During the day time water absorb a high amount of heat. During night time, it emits the highest land surface temperature comparing to other land uses. This response is due to a rather high thermal inertia, relative to typical land uses. Thus, it heats less during the day and keeps that heat more at night and has the highest night LST. Forest has the lowest night LST. It is related to cooling effect of evaporation and evapotranspiration.

Table 1 - descriptive analysis of night LST values

| SUMMARY | | | | | | |
|---------|---|--------------|------------|--------------------|-----------------|------------------|
| | <i>Groups</i> | <i>Count</i> | <i>Sum</i> | <i>Arith. Mean</i> | <i>Variance</i> | <i>Std. Dev.</i> |
| 1 | Open agriculture, 5 pixels | 1498 | 7089.94 | 4.733 | 44.585 | 6.677 |
| 2 | Build-up area, 5 pixels | 1894 | 13540.68 | 7.149 | 51.906 | 7.205 |
| 3 | Recreational area, 2 pixels | 725 | 3843.99 | 5.302 | 54.894 | 7.409 |
| 4 | Greenhouse farming, 5 pixels | 1969 | 10457.79 | 5.311 | 36.062 | 6.005 |
| 5 | Forest, 5 pixels | 1385 | 6042.57 | 4.363 | 59.287 | 7.700 |
| 6 | Inland waterway and Offshore area, 5 pixels | 1571 | 12598.19 | 8.019 | 56.292 | 7.503 |

Tab. 2 shows the result of applying the ANOVA test. F statistic indicates the amount of overlap group distributions. If the differences between groups are higher than the differences within the groups, the F value gets larger and the null hypothesis gets rejected. The null hypothesis for F

test claims that all the means are equal. The alternative hypothesis argues that not all the means are equal and at least one of them is different. Tab. 2 indicates that the F test is significant at the level of 0.01 and null hypothesis is rejected.

Table 2 - The result of ANOVA test for night LST

| | Sum of Squares | df | Mean Square | F | Sig. |
|----------------|----------------|------|-------------|--------|-------|
| Between Groups | 16244.701 | 5 | 3248.940 | 65.800 | 0.000 |
| Within Groups | 446110.511 | 9035 | 49.376 | | |
| Total | 462355.211 | 9040 | | | |

As discussed above, null hypothesis is rejected. Clearly there is a difference among the groups. Additional analysis, called post hoc tests, is done to determine where the differences lie. Fig. 1

shows the mean value of forest and open agriculture is very similar. Greenhouse farming and recreational area also show similarities in mean value.

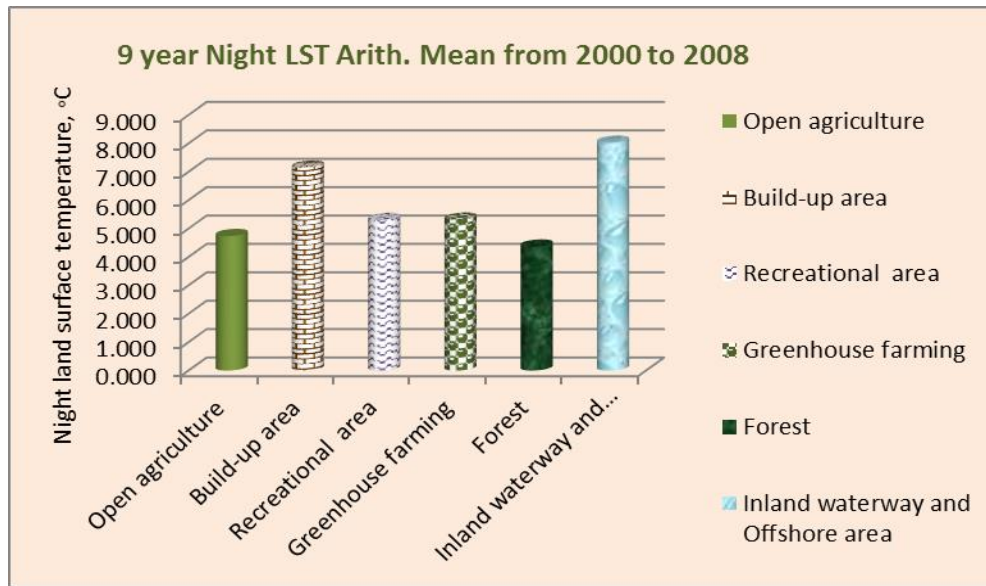


Figure 1 - Night LST arithmetic mean for different land uses

To capture statistically significant differences between the mean values of land use groups, Bonferroni analysis is applied. The result of Bonferroni test shows that open agriculture group is significantly different from build-up area and inland waterway and offshore area groups at the 0.01 level. While there is no statistically prove to consider open agriculture, recreational area, greenhouse farming and forest as different groups. Build up area is statistically significant ($P = 0.01$) from all other land use groups. Recreation area group is different from build-up are and Inland waterway and offshore area groups at significance level of the 0.05. It's mean is considered significantly different from forest ($P = 0.05$). Green house farming is significantly different from build-up are, inland waterway and offshore area and forest groups. Forest is a separate group from build-up area, inland waterway and offshore area and greenhouse farming at the 0.01 significance level. Forest group also differs from recreational area ($P = 0.05$). Inland waterway and offshore area is

significantly different from all other groups at the 0.01 level. In summary, build-up and Inland waterway and offshore area are considered as separate groups.

ANOVA test for day time LST

Tab. 3 shows the descriptive results of analyzing 27 homogeneous land use MODIS LST pixels. Build-up area has the largest day LST. Inland waterway and offshore area has the least day LST. It is because of high heat capacity of water. As Tab. 3 indicates, water has the minimum day LST mean. Water can be considered as a cooler land use during the day. As discussed from night ANOVA analysis, water has the largest night LST among all land use types. Build-up area has the largest day LST. The findings of the current study are consistent with those of Weng et al., (2004) who found that commercial and industrial land had the highest temperature followed by residential land; the lowest temperature

was observed in forest and then in water bodies. The present findings seem to be consistent with other research of Guo (2012) which found that built-up areas with paved roads and residential and factory buildings have significant higher surface temperatures than other land cover types. Based on their study, vegetation have the lowest surface temperatures.

Possible explanation for high mean LST of paving materials is that paving and building materials are mostly dark and have a large heat capacity in one hand and a low reflectivity on the other hand

(Mallick, 2009). Moreover, natural land covers benefit from cooling effect of soil moisture, evaporation and transpiration.

Lowest day time LST in the current study is for green house land use. The reason is that greenhouse farming houses have highly reflective roofs. The variance value of LST has the largest amount for build-up area, indicating that these surfaces experience a wide variation in land surface temperature which could be because of different construction materials.

Table 3 - descriptive analysis of day LST values

| SUMMARY | | | | |
|---|-------|----------|-------------|----------|
| Groups | Count | Sum | Arith. Mean | Variance |
| Open agriculture, 5 pixels | 1859 | 25806.03 | 13.882 | 75.38114 |
| Build-up area, 5 pixels | 707 | 12083.37 | 17.091 | 110.6373 |
| Recreational area, 2 pixels | 1822 | 28032.6 | 15.386 | 82.37462 |
| Greenhouse farming, 5 pixels | 1838 | 23253.18 | 12.651 | 75.32547 |
| Forest, 5 pixels | 1800 | 23423.64 | 13.013 | 71.6768 |
| Inland waterway and Offshore area, 5 pixels | 1871 | 21870.19 | 11.689 | 49.70682 |

Tab. 4 shows the ANOVA test result for daytime LST. The result shows that the F value is statistically significant ($p = 0.01$). Thus the null hypothesis is rejected and at least the mean of one of

the land uses is not equal to zero. In other words, not all the means are equal and at least one of them is different.

Table 4 - The result of ANOVA test for day LST

| | Sum of Squares | df | Mean Square | F | Sig. |
|----------------|----------------|------|-------------|--------|-------|
| Between Groups | 23681.851 | 5 | 4736.370 | 64.309 | 0.000 |
| Within Groups | 728401.816 | 9890 | 73.650 | | |
| Total | 752083.667 | 9895 | | | |

Fig. 2 shows some similarities between the mean values of different land uses. For example, the mean day LST value for greenhouse farming and forest are almost the same. To find weather the near values are in the same groups, post hoc analysis is done. The lowest mean LST is observed in inland waterway and offshore area, followed by greenhouse farming, forest, open agriculture, recreational area and build-up area. The findings of the current study are consistent with those of Zhou et al., (2011), who found that the amount of LST becomes higher as the land use changed from vegetated areas to built-up lands. Campbell (2002) argued that temperature of different bodies is a function of their internal

properties including heat capacity, inertia and thermal conductivity. Build-up area has the highest day LST, which can be due to reduction of the water storage that strengthen the sensible heat flux (Zhou, et al, 2011). Non-evaporating and non-transpiring surfaces like paving and building materials have high absorptivity, high thermal capacity and low albedo. Based on NCHRP (2004), asphalt pavement has low conductivity (0.76-1.4 W/mK) which prevents the absorbed energy from being conveyed elsewhere; high absorptivity (0.85-0.93) of solar radiation coupled with relatively high thermal capacity (921-1,674 J/KgK) allows asphalt pavements to stock thermal energy and reach relatively high temperature

– usually higher than the neighboring air. Fig. 2 also shows that open agriculture has a larger mean LST than forest. This finding corroborates the ideas of Wickham (2012), who found that the average annual land surface temperature for cropland is higher than average surface temperatures for forest. This finding furthermore supports previous research of Davin and Noblet-Ducoudré (2010). They argued that evapotranspiration from forest produce a larger cooling effect than croplands. For dense forest

canopy, LST is collected from forest canopy. Therefore to compare forest with open agriculture, type of forest (evergreen, deciduous), and type of open agriculture (winter or summer farms) should be considered. Seasonal analysis can capture these variations better than annual LST values. In general, forest albedo is lower than cropland albedo. The color of soil, its water content and snow cover are among other important factors which impact surface characteristic (Bonan, 1997).

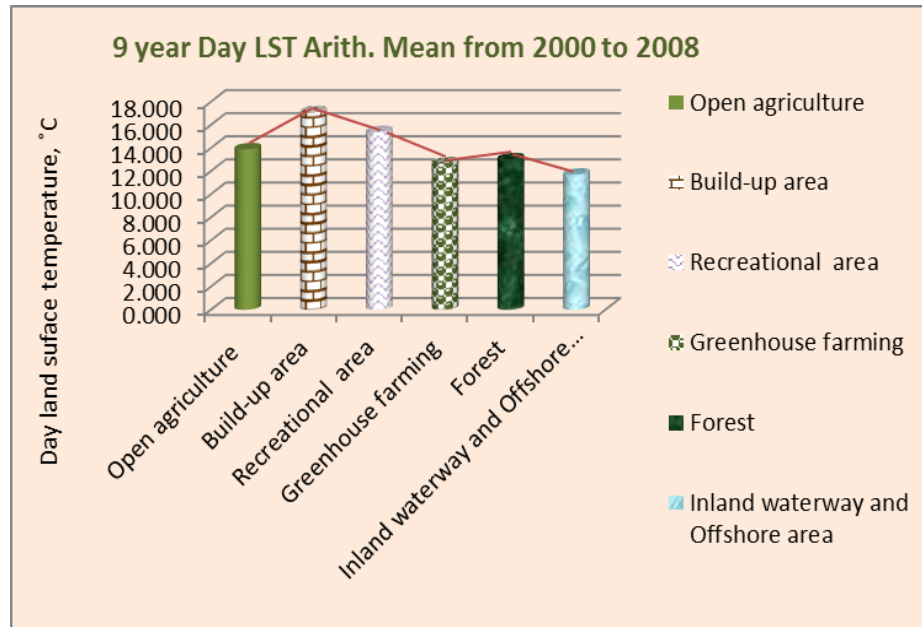


Figure 2 - Night LST arithmetic mean for different land uses

The LST shows similarities for forest, greenhouse farming, inland water and open agriculture. To allocate statistically different groups to these land use types, post hoc analysis is done. The result of Bonferroni test indicates that open agriculture is statistically different from forest at the significance level of 0.05, which supports the result of Wickham (2012). Open agriculture is separated from all other land use types at the 0.01 significance level. Build up area, inland waterway and offshore area and recreational area are considered as distinct land use groups ($P = 0.01$). Greenhouse farming is disjointed from all land use types ($P = 0.01$), except forest. Forest is statistically different from build-up area, recreational area and inland waterway and offshore area at the level of 0.01. Forest and open agriculture are allocated to different groups at significance level of 0.05. In summary, forest and greenhouse farming are considered as a jointed group. However, the findings of the current part do not support some of the previous research of Quattrochi and Ridd (1998) that argued that thermal

responses for vegetation can be highly different as a function of the biophysical properties of the vegetation. For any surface material, certain internal properties play important roles in governing the temperature of a body at equilibrium with its surroundings (Campbell, 2002). These thermal properties vary with soil type and its moisture content (Sandholt et al., 2002). Biophysical characteristics of different vegetation types affect the thermal behavior of different green land covers (Weng, 2004).

Tab. 5 and Fig. 3 indicate the difference between day and night LST values for different land uses. LST is normally defined as soil surface temperature for the bare soil surface. For dense vegetated ground, LST is the canopy surface temperature and for sparse vegetated LST is determined by the mixed temperature of the vegetation canopy, vegetation body and the soil surface (Qin and Karnieli 1999).

Build-up area and open agriculture has the largest LST difference between day and night values.

One interesting point is inland water LST pattern. Inland water has the maximum night LST, minimum day LST and the minimum LST difference between day and night. This is because the water temperature changes slowly due to high thermal inertia and convection (Sun, 2012). After inland water the lowest mean difference is for greenhouse farming, followed by forest, open agriculture, build-up area and recreational area. The present findings seem to be consistent with other research of Kant et. al (2009), which found commercial/industrial and high dense built-up area to have high surface temperature values during day time, compared to water bodies, agricultural cropland, and dense vegetation. They also argued that night LST values are higher in dense built-up and water bodies, than in dense vegetation and agricultural cropland. Recreation is a mixed land use and it is not easy to interpret its LST behavior. The mean day and night LST difference of forest is 8.65 degree Celsius which is less than the open

agriculture with 9.14 degree Celsius. Based on Goulden et. al (2006), and due to night drainage of cold air from upper canopy layer to ground level, upper levels of canopy are warmer than forest ground level. This process is more sensible in intact forests rather than sparse and short vegetation. Based on the process described above, intact forest shows a higher night LST than short vegetation and bare ground. Consequently the LST difference between day and night is lower (Goulden et al., 2006). The reason is that satellite sensors only measure the temperature of the top of forest canopies. High difference between open agriculture and build-up area LSTs can cause a strong UHI between build-up area and the surrounding open agricultural farms (Xu, 2010). Based on table 5, the difference between build-up area and open agriculture land uses is 3.20 degree Celsius for day time and 2.41 degree Celsius for night time.

Table 5- The mean difference between day and night LST

| | <i>Arith. Mean(day)</i> | <i>Arith. Mean(night)</i> | Arith. Mean (Day-Night) |
|-----------------------------------|-------------------------|---------------------------|-------------------------|
| Open agriculture | 13.882 | 4.733 | 9.149 |
| Build-up area | 17.091 | 7.149 | 9.942 |
| Recreational area | 15.386 | 5.302 | 10.084 |
| Greenhouse farming | 12.651 | 5.311 | 7.340 |
| Forest | 13.013 | 4.363 | 8.650 |
| Inland waterway and Offshore area | 11.689 | 8.019 | 3.670 |

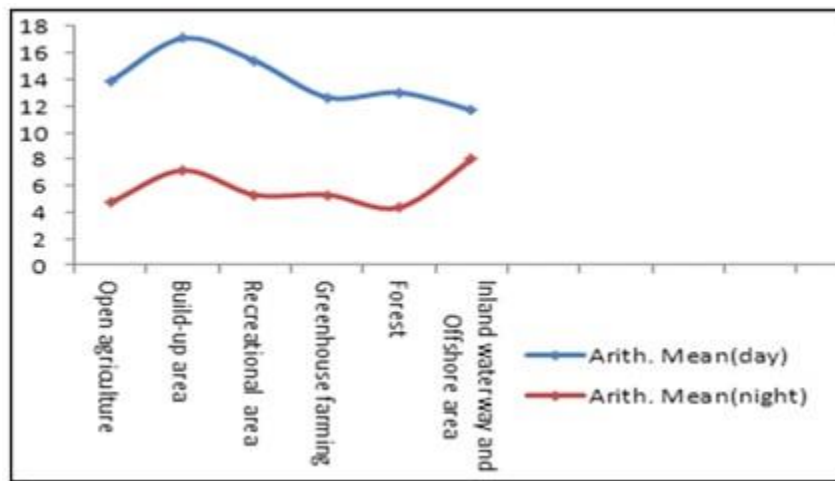


Figure 3- The mean difference between day and night LST, Figure shows the difference between mean day and night LST for different land use types

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