**DIMENSI** − Journal of Architecture and Built Environment, Vol. 42, No. 1, July 2015, 35-42 DOI: 10.9744/dimensi.42.1.35-42
ISSN 0126-219X (print) / ISSN 2338-7858 (online)

# TEMPERATURE MAPPING OF PETRA CHRISTIAN UNIVERSITY MAIN CAMPUS SURABAYA

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## ABSTRACT

Petra Christian University (PCU) is a university in Siwalankerto, a suburban area of Surabaya city, East Java-Indonesia. It is well developed at Siwalankerto that has been crowded with surrounding buildings. This research objective is to find the temperature mapping of PCU. The method is used by calculating all the land coverings including the built areas, the pavements, the green areas, mapped by the *Screening Tool for Estate Environment Evaluation* software-*STEVE tool.* The field measurement was also conducted. The results then be analyzed, which lands cover that gives more impact to the ambient air temperature. The climate components reviewed are the minimum, the average and the maximum ambient air temperature in degree Celcius. This research found that the lowest ambient air temperature mapped both by field measurement and STEVE-tool is the Zone 5; while the highest ambient air temperature of the STEVE-tool is the Zone 4; but from the field measurement found that the hottest is the Zone 3. This different results give an input for later STEVE-tool improvement.

**Keywords:** Petra Christian University main campus; STEVE-tool; temperature mapping.

## INTRODUCTION

Temperature increases at land area makes the urban heat island phenomena. That condition influence the thermal discomfort of people activities at outdoor area and increase the indoor temperature that affects the energy using for indoor cooling. Petra Christian University as a well-developed university in Surabaya, in its development gives impact to Siwalankerto land temperature. As of the green campus campaign, PCU responsible to make a better environment that later can decrease the urban heat island in the micro-climate of Siwalankerto land. By this research, PCU called ‘an urban lab’ since it can represent the ‘city’ in lesser scale.

The temperature of urban area influenced by its land coverings, such as building (BDG), pavement (PAVE), greenery area, etc. These elements represents the research parameter, consist of pavement percentage (PAVE), average ratio of building height compare to the built area (BDG), total area of wall surfaces (WALL), green plot ratio (GNPR), daylight factor (DF), and the average of surface albedo (ALB).This research analyzes the influence of each parameter into the temperature of ‘urban lab’, the PCU main campus. From the result of this research, can be recommended the land coverings formulae that can decrease the temperature of this urban lab so that can give better impact for the wider land area.

### Research Objective

The objective of this research is to describe the kinds of site enclosure related to the temperature and to learn how the green open-spaces influence to a more comfortable environment; so that a better future planning can be developed, especially for PCU development.

This research is held, refer to the condition of there’s no temperature mapping as impact of the variations of site enclosure in urban area of Surabaya. The dependent factor is the air temperature; while the independent factors are the site enclosures: the pavement area, built area, green plot ratio and surface albedo.

## THEORETICAL APPROACH

### Urban Heat Island Phenomena

Table 1 listed some researches of *urban heat island* (UHI) from Emmanuel (2005).

The research conclude that there is correlation between the UHI phenomena and the air temperature and the relative humidity. In an urban area, the air temperature in the afternoon tends to hotter, besides in the night, the air temperature that should be cooler, becomes hotter. As a comparison to the suburban and rural area, the relative humidity of urban area in the afternoon tends to drier while in the night the RH tends to more wet.

### The Influence of Site Enclosure to Built Environment

According to Jusuf (2009), in air temperature prediction tool called *Steeve tool*, the elements of air temperature related toward site enclosures arethe T-min, T-max and T-ave. Hipothese from *Steeve tool* “the air temperature in a point referentis a function of its micro-climate character, which the ‘swing’ depends to the urban morphology (the built area, the pavement, and the green area) in a distinct radius/ distance.

**Table 1.** Recent Tropical Urban Heat Island Studies

| Author/s | City | Parameter/s studied | Major finding |
|---|---|---|---|
| Nichol (1996a, 1996b) | Singapore | Remotely sensed surface temperature | Due to high solar azimuth, horizontal surface temperatures are more representative of urban air temperatures in the tropics. Tropical cities do not have a single UHI; rather a collection of small UHIs separated by cooler areas. |
| Jauregui and Romales (1996) | Mexico City | Convective precipitation | Wet season rainfall, as well as the frequency of intense rainfall (>20mm/hr), appears to have increased over the city. The latter is related to daytime UHI. |
| Jauregui and Tejeda (1997) | Mexico City | Specific humidity | City is drier during the day and wetter during the night than rural areas. The city-rural differences also dwpwnd on the season (smaller during dry season and larger during wet season) |
| Jauregui (1997) | Mexico City | Air temperature | Nocturnal heat island was more frequent (75% of the time) than daytime heat island (25%). Daytime heat island may have been caused by differences in evaporative cooling from wet surface during wet season. |
| Jauregui et al. (1997) | Mexico City | Air temperature and relative humidity | The heat-island effect reduces the 'cold' nights to 'cool' and 'cool' nights to 'comfortable' bioclimate (as measured by effective temperature-ET) |
| Barr-Kumara-kulasinghe (1997) | 16 cities in South India and Sri Lanka | Air temperature | Negligible temperature trends were seen in all but one city (Colombo, Sri Lanka) |
| Deosthali (1999) | Pune, India | Wet and dry bulb temperature | Rising trends in annual and monthly thermal comfort (THI), particularly during the day. The presence of a 'moisture island' detected. |
| Oke et al. (1999) | Mexico City | Net radiation, sensible and latent heat fluxes | During daytime, the heat uptake by buildings is so large that convective heating is severely suppressed in the central city with massive stone walled buildings. The heat release at night is equal to or larger than net radiation. |
| Wienert and Kuttler (2001) | Several cities | Air temperature differences between city and rural areas | UHI magnitude is linked to latitude (low latitudes have smaller UHI), but this correlation is largely explained by differences in anthropogenic heat and radiation balance. |
| Emmanuel (2003) | Colombo | Air temperature and relative humidity | Thermal comfort patterns (THI) are strongly correlated to hard land cover changes, particularly in the suburban areas. |

Knowles (1977) published a theory of the influence of thermal mass to its environment in a distinct radius. According to Knowles, found that ratio of average building height to total area, give result as a thermal mass that influence its environment in a distinct distance.

A research that have been conducted in a residential area in Semarang by Maidinita et al. (2009), found that thermal comfort in outdoor living area gets when the pavement area less than 25% of its site enclosures. And she suggests for 40% of green area prevention.

Agus B.P. (2003), in his research on A Campus, Trisakti University Jakarta, found that shadow pattern of building and greenery gives positive impact to the ambient air temperature. The vegetation especially 'a tree' can decrease the wet bulb temperature by its evapotranspiration process. While pavement of different materials composition can decrease thermal radiation and bring up the decreasing radiant temperature.

## Impact of Vegetation

Robinette (1973) stated that the impact of greenery in urban area is more significant in blocking the solar radiation than its impact in decreasing the air temperature. While Yoshikado & Tsuchida (1966) in Widigdo & Kristanto (2006) stated that in tropical climate region, the air temperature tends to increase because of the low wind speed, bring up the UHI phenomena that can be decreased by vegetation added to open spaces.

Oke (1989) in Widigdo & Kristanto (2006), stated that vegetation can prevent the lower urban air temperature. Further, according to Oke (1989), Shasua-Bar and Hoffman (2003) in Widigdo & Kristanto (2006), the influence of green open spaces although insignificant (only about 1-2 K); its impact to prevent the air temperature cooler is the more importance. In Widigdo & Kristanto (2006); Ames (1980), Ulrich (1984) and Wileke (1989) stated that other positive impacts of green open spaces are psychological factor to the people.

In a research of Tauhid et al. (2008) in Semarang, suggests 30% vegetation as land coverings in urban area is just significant in micro-climate amelioration; especially its effect to air temperature. Also stated that vegetation give just little impact to air temperature compared to wind speed and wind direction.

From Lay (2003) and Shuvo (2008), *Green Plot Ratio* (GPR) is an average value of *Leaf Area Index* (LAI) which represents the total area of leaves surface among different kind of vegetation such as grass, shrubs and trees expose to sun; in a coefficient of 1, 3, and 6 to 10. So, an area fully covered by grass gets 1:1 GPR, while fully covered by shrubs and trees gets GPR 6:1 and 10:1.

## RESEARCH METHODOLOGY

Schematic of research methodology as follows:

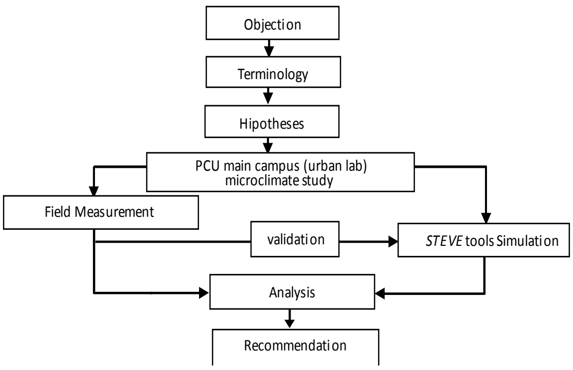


**Figure 1**. Research method schematic

### PCU Main Campus Microclimate Study

Petra Christian University (PCU) represents 'a city' in micro scale (see PCU site plan).The object studied is the main campus of PCU, which has green open space in its core surrounded by medium-rise buildings. The buildings are pitched roof with zincalum as its cover material. The lower air temperature can bring up more comfortable outdoor spaces for student activities.

From site plan, the main campus then divides into 5 morphology zone, according to green area, pavement and buildings composition. Then, the micro climate study carried on in 50 m radius. The object studies are pavements, building height, total built area, wall surfaces, the kind and ratio of greenery area, daylight factor and surface albedo.

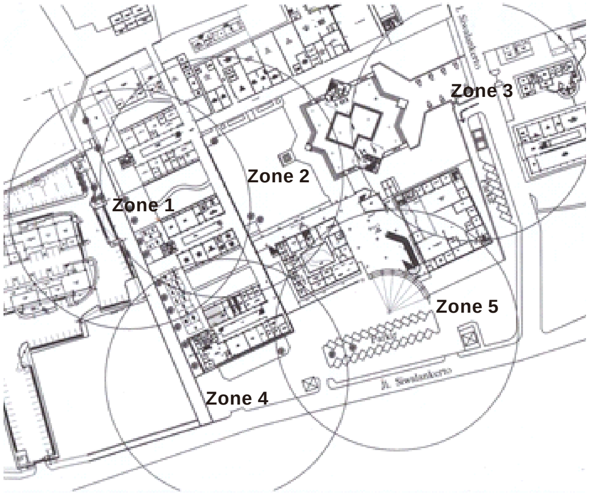


**Figure 2**. Site plan and morphology zone of PCU main campus

### Field Measurement

The devices used in the field measurement is HOBO Data logger with sun radiation protection. It is placed in the middle of every zone, in 3m high for its safety.

The Steve Tools software built with RH ignorance, so that the optimum condition for field study is in dry season (Jusuf, 2009). The field measurement carried on 2 periods in 2 weeks each period. The first period was on 18-31 May 2012, and the second was on 17-30 October 2012.

### Steve Tool Simulation

Steve tool (Screen-tool for Estate Environment Evaluation) build in two prediction (Jusuf, 2009). The former is an urban lab microclimate prediction, consist of daily minimum temperature (T-min), average temperature (T-ave), and maximum temperature (T-max). All this data got from Juanda meteorology station and field measurement. While the solar radiation taken from field measurement because it was not taken by the Juanda station. The latter prediction is the urban morphology; consists of pavement percentage in 50 m radius (PAVE), building height ratio in each zone (HBDG), total wall area in each zone (WALL), Green Plot area ratio (GNPR) ratio of total leaf area divide by total greenery area in each, daylight factor got from average D/H (building height vs canyon height) of buildings in each zone; and the average surface albedo (ALB). All the points then being input to Steve tools software, and the result is as follows:

**Table 2.** Morphology data of each zone

| | ZONE 1 | ZONE 2 | ZONE 3 | ZONE 4 | ZONE 5 |
|---|---|---|---|---|---|
| PAVE (%) | 31.57 | 21.41 | 52.64 | 25.82 | 65.51 |
| BDG (%) | 41.69 | 48.09 | 33.52 | 48.16 | 23.77 |
| Green area (%) | 26.74 | 30.5 | 13.84 | 26.02 | 10.72 |
| GnPR | 54.51 | 35.79 | 93.41 | 29.2 | 167.2 |
| - luas area hijau | 524.77 | 598.56 | 271.61 | 510.64 | 210.38 |
| - total leaf area | 28602.78 | 21420.71 | 25370 | 14909.94 | 35176.55 |
| AVERAGE HEIGHT (m) | 8.56 | 11 | 11.72 | 6.92 | 8.93 |
| WALL | 6399.5 | 4041.4 | 6940 | 3130 | 1372.5 |
| ALB | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| - average canyon width | 24.68 | 32.14 | 20.01 | 35.48 | 35.35 |

## RESULT AND ANALYSIS

### The Result and Analysis of Field Measurement

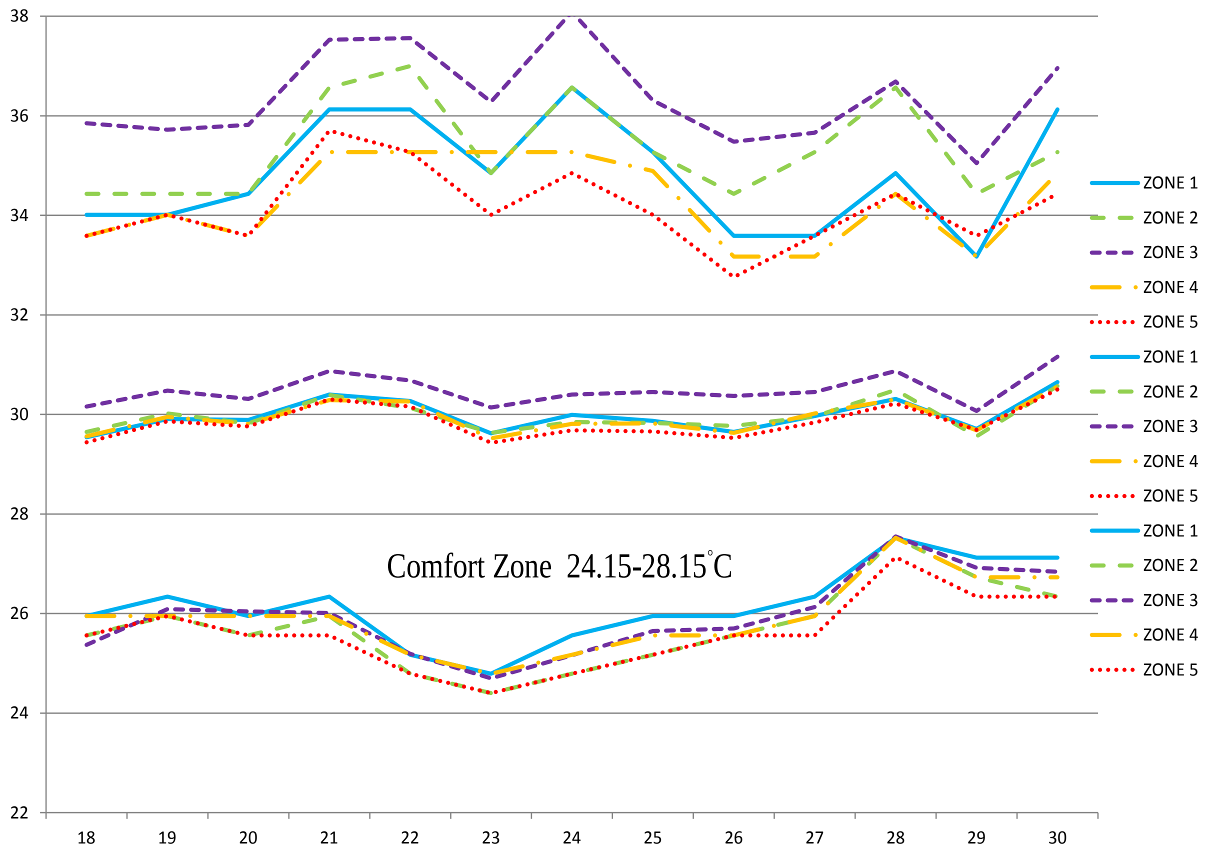


**Figure 3.** Temperature Profile of Field Measurement

The figure 3 showed the result of field measurement. The lower temperature indicated the comfort zone, happened in the morning, at 24.15 - 28.15°C; the average temperature at 29.35 - 31.3 °C; and the highest temperature at 32.8 - 38.15°C. The coolest zone is the Zone 5, followed by Zone 4, Zone 1, Zone 2 and Zone 3 as the hottest zone. Zone 3 becomes the hottest zone because it is dominated by the Siwalankerto street (PAVE) ratio 52,64 %, while the green area ratio (GNPR) 93.41, the WALL is 6940 $m^2$ and the built area (BDG) ratio is 33,52%; that contributes to its hottest temperature. Zone 5 becomes the coolest zone, since its pavement (65.51%) covered by shady trees that contribute to green area ratio (GNPR)167.2, the WALL is 1372.5$m^2$, while the built area (BDG) ratio is only 23.77%.

## The Result and Analysis of STEVE tool Simulation

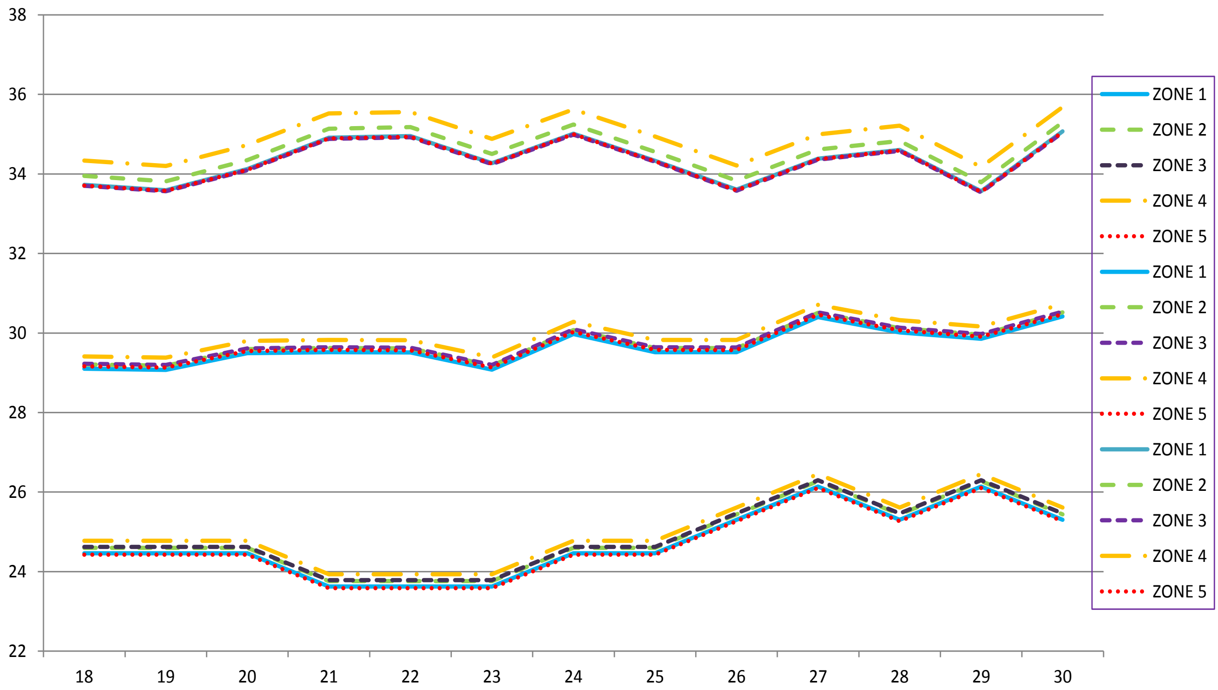


**Figure 4.** Temperature profile of STEVE tool Simulation

The result of STEVE tool simulation shown that the temperature difference of each zone is not as significant as the field measurement.The coolest is the Zone 5 followed by Zone 1, Zone 3, Zone 2 and Zone 4 as the hottest zone. The coolest zone is the same as field measurement; while the hottest zone is Zone 4. It can be explained that the different result happened because STEVE tool is simulated all the radius 50m$^2$, while the field measurement taken only in one point on each zone.

### Validation

Validation conducted by verifying the simulation result to the field measurement. The data compared are the maximum air temperature (T-max), average air temperature (T-ave) and the minimum air temperature (T-min) of each zone.

From the fugure 5 found that the deviation of the air temperature in all zone not more than 2 K, so that it can be concluded that the simulation and field measurement are identical. The deviation represents some of these points:

- The data min, max and average air temperature of Juanda meteorology station is taken in 0.5 point accuracy.
- All building forms are simplified to a cube; so that their declinations, bends, or consoles at vertical planes at the roof, balconies, shading are to be ignored. It brought up non accurate data of building and canyon height (HBDG) and wall surfaces (WALL).
- Building height and canyon height ignore the quantity and quality of each building proportion; so that influence the HBDG and SV result.
- All vegetations are simplified as 'oval' form. The characterof greenery only differs by its leaf density; so that its non-physical factors such as its absorption, color and condition are to be ignored.

## CONCLUSION

From the field measurement and STEVE-tool simulation, it found that the outdoor comfort air temperature at Petra Christian University main campus only happen in the morning. Besides, in the afternoon the air temperature is always above the temperature neutrality. Zone 3 and zone 4 as the hottest zone represent that the land covering dominated with pavement causes the hotter air temperature while the more open green area couses lower air temperature as in zone 5. By this research, some of consideration for later experiment are the similarity of land coverings and the morphology of each zone; besides the quantity and position of field point of measurement taken.

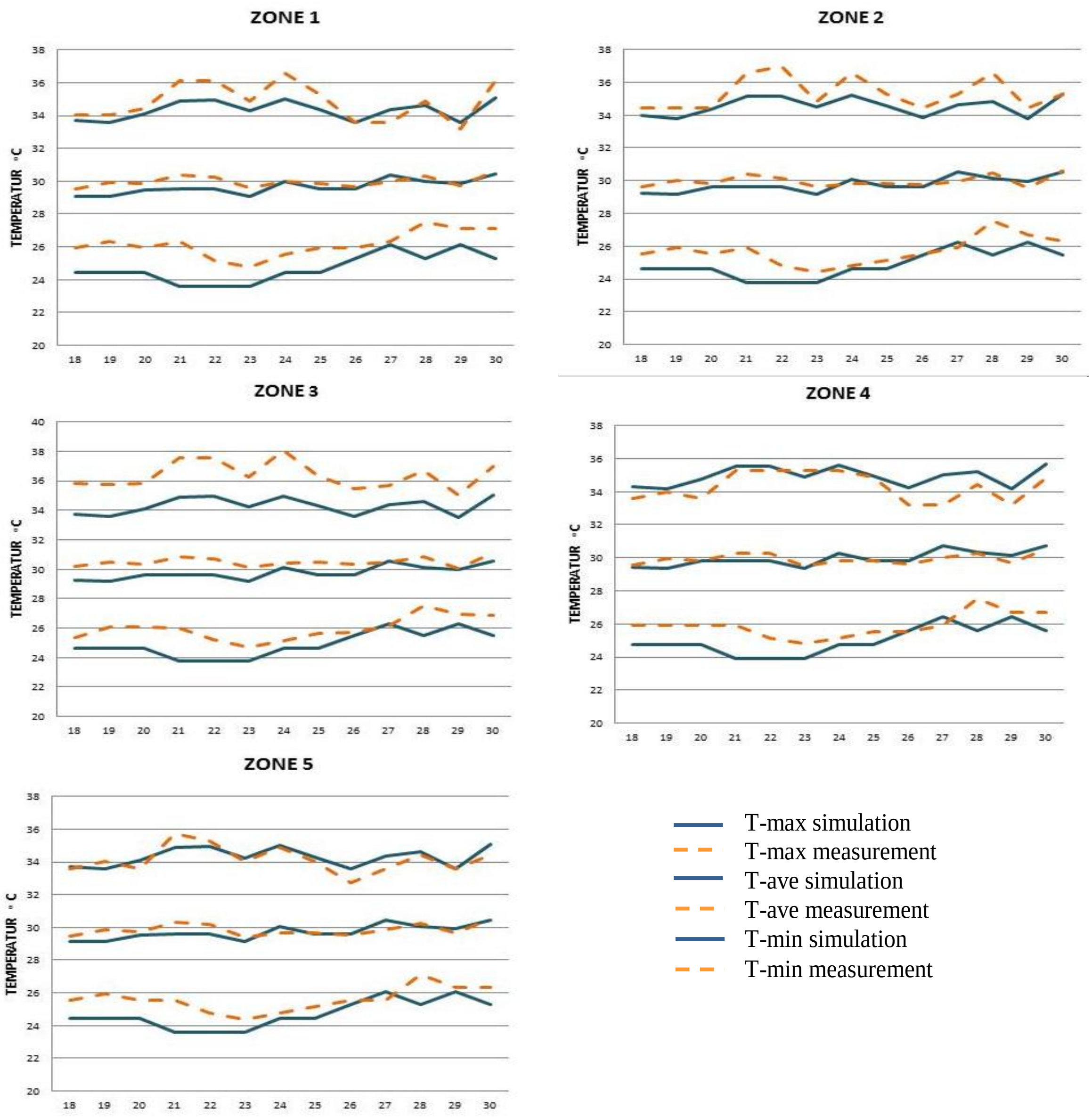


**Figure 5.** Validation air temperature of Steve tool simulation vs field measurement in each zone

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