

## **IMPACT OF INFLUENCE OF VEGETAL ROOFS SURFACE ON THERMAL COMFORT IN HOUSING IN THE SAHEL REGION**

### **ABSTRACT**

The concern for improving thermal comfort in housing has led ~~man~~ to focus on the temperature ~~that mainly influences thermal comfort~~ inside the building. ~~In a building,~~ ~~a~~~~All the walls~~ ~~in a building are likely to~~ receives and transfers heat, ~~whereas but~~ the roof contributes significantly to heat ~~transferexchange more than the other walls~~. The simulation results ~~using with~~ the COMSOL software for ~~the~~ three types of roofs ~~have been obtained~~. The results show that ~~inside the habitat with a green roof~~, the average temperature ~~inside a house with a green roof~~ is around 27°C compared to 36°C ~~in the case of a concrete slab~~. The inside ~~temperature of a house with a metal the flat-roof is building and~~ 40°C ~~inside the metal roof building~~. ~~The current~~ ~~In this study~~ ~~has~~, we have ~~defined~~ two objectives. The first objective was to compare the interior temperature of a ~~house habitat~~ with a green (vegetal) green-roof, ~~to that of a habitat with a metal roof~~ or ~~a concrete slab-roof~~. The second objective was to study the effect of the green roof on thermal comfort. ~~The study was conductd~~ in the ~~habitat in the~~ Sahelian ~~z~~Zone. The simulation results ~~obtained~~ show that the temperature inside the green roof is lower compared to two other types of roofs. The green roof ~~better~~ ensures good thermal comfort for the occupant.

Keywords : green roofs, metal roof, concrete slab, thermal comfort, biodiversity, evapotranspiration.

## INTRODUCTION

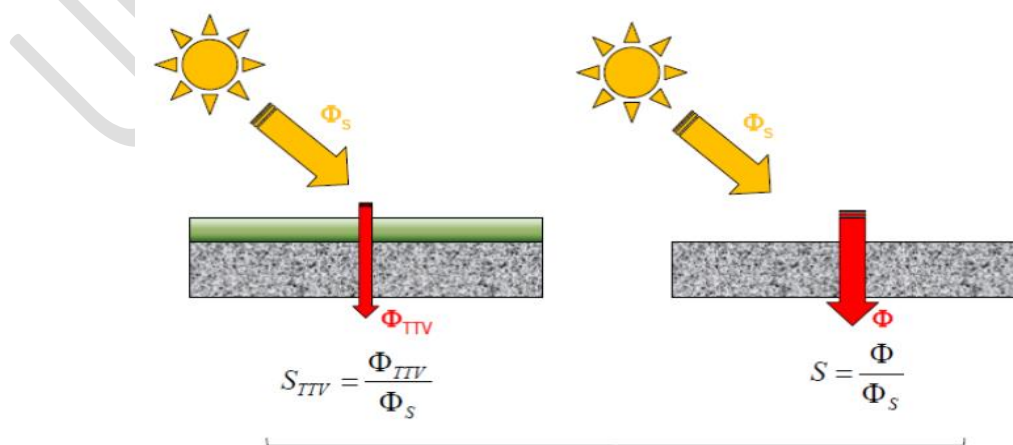
~~In Burkina Faso~~The solar radiation is very intense in Burkina Faso. significant; "tThe solar energy potential per km<sup>2</sup> is estimated at 1500 GWh/year based on the assumption of a production of around 4 to 6 kWh/m<sup>2</sup>/day" [1]. The intense solar radiation prevails in affects a large part of the country with high temperatures. The high temperature It also results in more than 40% of incoming energy is absorbed by the roof. impacts the roofs of buildings, which absorb more than 40% of energy consumption [3i] which and influences the thermal comfort in the dwellingside the building. The recommended thermal comfort zone for an adult subject person inside the building lies between is generally an air temperature between 17°C to and 22°C of temperature and relative humidity between 40% to and 60%, with a difference between the average temperature of the surfaces of the walls, floor, and ceiling (mean radiant temperature) and the air temperature [1i]. For the human body, the ideal temperature for a normal person is between 36.5°C and 37.5°C [2i]. -This contradicts the previous statement. Pl check ?? In hot and dry countries like Burkina Faso, the comfort zone is defined within a temperature range of 20 to 27°C Yezouma COULBALY [2] and relative humidity of ... ?. The For human health, it is noted that the body cannot withstand intense heat of greater than .... ?. In temperature higher than .... The body ~~It~~ quickly becomes dehydrated due to a lack of water for ~~its~~ proper functioning, leading to fatalities. According to the Mali Actu newspaper dated April 30, 2019, "more than 550 people have died due to the intense heat" [3]. It is therefore paramount important to seek appropriate methods to lower teamperature inside the house and thereby to support human health Mechanisms must be sought to protect it. How can we mitigate the effects of heat on habitats and on people ? Research shows According to the results from some authors,that green roofs helps in ensure thermal insulation of a

dwelling, reduces heat buildup, and decreases air conditioning needs [4]. A Greening roofs with a substrate thickness of 70 cm reduces the air temperature inside the building by as much as 7°C for a substrate of 70cm thickness. It also The green roof helps to decrease thermal flux inside the room and decreases noise improves its sound performance by 15 to 20 dB depending on whether the substrate of the green roof is dry or saturated with water.

This study Subsequently, we will conduct a temperature modeling study inside a house that has three the different types of roof materials namely, (vegetal matter (green), metal and concrete, slab). Comparing the temperature inside the house, tThe study is will allow us to assesses the which type of roof that provides meets the thermal comfort needs for humans in our habitats.

### 1- Physical model of green roofs and flat roofs with bare surfaces

The objective of this article is to compare the thermal comfort beneath a provided by green roof, s to that of flat or metal roof and a concrete slab. Figure 1 shows the effect of reduced heat transfer within a entering the building with provided by a green flat roof covered by green surface (GFR) compared with to a bare flat roof (BFR).



Label parts ; define formulae

**Figure1 : Change in Reduced Heat Transfer by Roof Type building penetration due to green roof terrace**

**1.1- The Concept Modeling of the system**

Figure 2 shows a cross section of a roof cladded with a vegetal matter (green). The diagram of the prototype of a habitable cell with a green roof is shown in Figure 2. Figure 3 provides an explanation of heat transfer mechnism beneath a green roof explains the different thermal exchange phenomena produced between the green roof and the atmosphere. Explain : Fig 2 is not clear ; why no continuity in plant cover ; what is L1, L2 etc ? slab of room. Explain that evapotranspiration takes heat from the roof and helps reduce surface temperature at the roof.

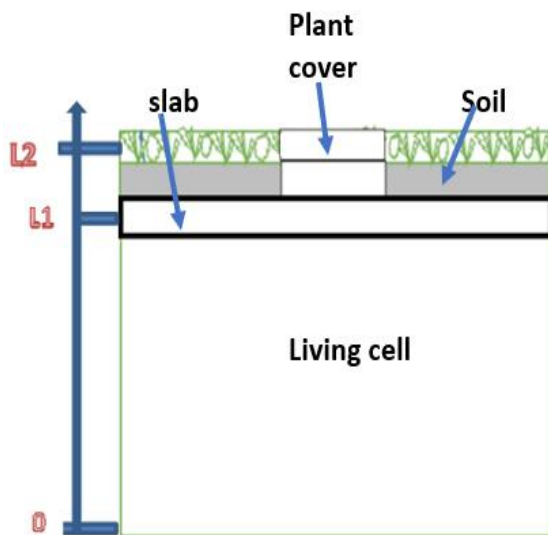


Figure 2 : Structure Diagram of the living cell prototype with green roof

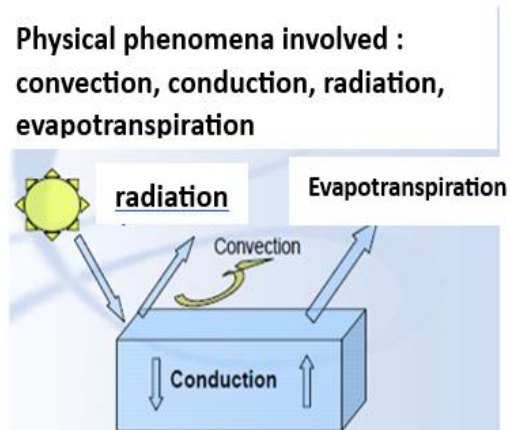


Figure 3 : heat transfer phenomena of a green roofs

**1.2- Boundary conditions explain formulae. Define boundary condition**

The boundary conditions are defined as follows:

$$z=0 ; \phi_0(t) = \alpha \cdot P_w(t) + h(T(t) - T(t)_{sheet}) - \dot{m}_e \cdot L_v$$

$$z=L1 : T2(L1,t)=T3(L1,t)$$

$$z=L2 ; T3(L2,t)=T4(L2,t)$$

These equations are introduced into a calculation program using the finite element method of Comsol software. Statement is not clear ??

### 1.3- The Modeling Hypothesis

We assumed ~~that the different~~several types of heat transfers ~~considered occur~~ as follows:- Conduction takes place ~~at the etween the roof, the ground, and the slab~~;- Convection occurs from the ~~surface of the roof inside of the room to the outside (roof)~~;- Radiation is manifested ~~from~~ inside the rooms ~~through the absorption of materials~~;- Evapotranspiration ~~occurs proceeds through a gain of energy to release the amount of water stored in the roofs from plants by taking energy from the roof~~ .

## 2- Heat transfer equations

### 2.1- At the level of the vegetation cover and the soil

Here we use the assumption that transfers are predominant along the z-axis. The vegetation cover and the soil are modeled in a porous medium having an interface with the air. A phenomenon of evapotranspiration thus simplifies a convective exchange between the leaves and the atmosphere. The convective exchange is defined by equation (3). This paragraph is not clear ??

$$(\rho C_p)_{\text{eff}} \frac{\partial T_2}{\partial t} + \rho C_p \cdot \vec{V} \cdot \nabla T_2 - \lambda \Delta T_2 = \text{alfa} \cdot P_w + h(T - T_{\text{feuille}}) - \dot{m}_e \cdot L_v \quad (3)$$

$$\text{avec : } (\rho C_p)_{\text{eff}} = \theta_p \rho_p C_{p,p} + (1 - \theta) \cdot C_p$$

$$\lambda_{\text{eff}} = \theta_p \lambda_p + (1 - \theta) \cdot \lambda$$

$P_w$  = solar power received on the roof ;

$\text{alfa}$  = solar fraction intercepted ;

$\dot{m}_e = 0.2083$  [kg/h] mean evapotranspiration ;

$\theta_p$  = porosity ;

$C_{p,p}$  = specific heat of water ;

$C_p$  = specific heat of dry soil . specific heat of plant material ?? Label all other éléments in the formula ...

### 2.2- At the level of the concrete slab

The concrete slab is governed by ~~solid the classic equation of~~ heat transfer ~~in a solid~~ defined by equation (4).

$$(\rho C_p)_{\text{concrete}} \left( \frac{\partial T_3}{\partial t} + \vec{V} \cdot \overrightarrow{\nabla T_3} \right) = +\lambda_{\text{concrete}} \Delta T_3 \quad (4) \text{ label all éléments ...}$$

### 2.3- Regarding the air volume of the isolated habitable cell

Within the confines of the habitable cell, the movement of the air volume ~~—why we talk~~ about air when we should be talking about temperature ?? is characterized by a thermal exchange ~~—between what ??~~ defined by equation (5).

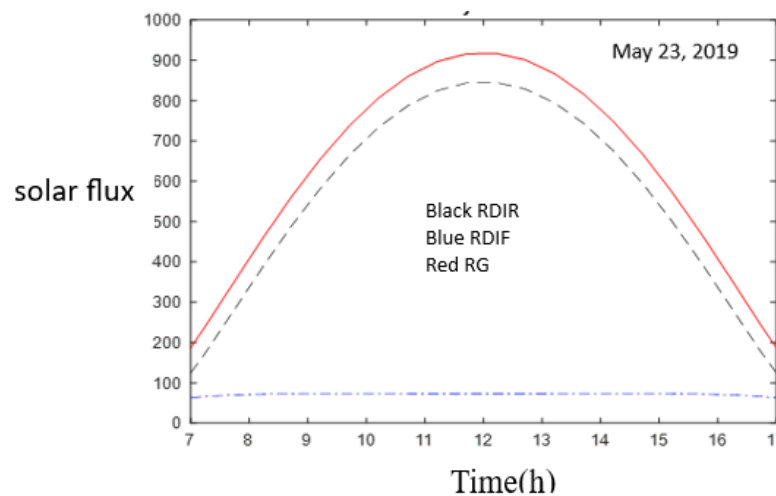
$$(\rho C_p)_{\text{air}} \left( \frac{\partial T_4}{\partial t} + \vec{V} \cdot \overrightarrow{\nabla T_4} \right) = +\lambda_{\text{air}} \Delta T_4 \quad (5) \text{ define éléments... ?}$$

### 3-Results and Discussion

The objective of the simulation is to determine the variation of solar radiation from 7 AM to 5 PM inside a room that has a green roof, metal roof and a concrete slab. We have chosen over the course of the day on May 23, 2019 as the date for this experiment. Why thos date wass chose ? anything specific on this day ? This variation in radiation allows us to determine the thermal flux inside the room. The greater the radiation, the larger the flux ...meaning ?. For the case of our research, we will study the evolution of temperature for each type of roofing and within the room in relation to solar radiation. Figure 4 shows the variation of solar radiation from 7 am to 5 pm on for the day of May 23, 2019.

Variation in Radiation of a typical day ~~on~~ (May 23, 2019)

### Define solar flux ? Time of the day from 7 am to 5 pm



**Figure 4** : Variation of solar radiation as a function of time on May 23, 2019.

~~The thermal conductivities of the materials of the three types of roofs~~  
We ~~have analysed considered~~ three types of ~~roofing materials~~ namely reinforced concrete, iron ~~and~~, plant ~~surface fibers~~ with respective thermal conductivity  $\lambda_1=1.5$   $\lambda_2=72$   $\lambda_3= 0.05$ . When the thermal conductivity of a material is low, its thermal resistance ( $R/h = e/\lambda$ ) is high and the heat flux through it is low. From these three types of materials ~~tested~~, we ~~can see remember~~ that ~~heat flow via plant material fiber has difficulty passing through the heat flow due to its is~~ low thermal conductivity compared to ~~two~~ other types of materials. ~~Roof with a plant material has produced the lowest heat transfer.~~

### **3.2- Evolution of the temperature in the green roof and in the insulated room.**

The simulation ~~using with~~ the Comsol software allowed us to ~~determine~~ graphically ~~represent~~ the curves of temperature variations (figure 6); the red curve represents the ~~evolution of the~~ temperature ~~on of~~ the ~~concrete~~ slab, the blue curve shows the ~~evolution of the~~ ambient temperature, and the green curve indicates the ~~evolution of the~~ internal temperature of the room. ~~The Under the effect of~~ solar radiation ~~heats up,~~ the temperature of the slab ~~to reaches~~ 31.5°C ~~within 24 hours ... No.. it should not take 24 hours to heat up.. perhaps in 4-5 hrs max ?~~. The temperature in the room is 28°C and the ambient air temperature is 27.25°C compared to ~~.. what ?~~ 28 to 30°C, which is the comfort temperature in the context of hot and dry countries, resulting in a gap of -2°C Madiana HAZOUME[9]. ~~Reword the sentence...~~ The presence of vegetation cover

helps to reduce the temperature that reaches the surface of the slab. Consequently, the temperature inside the room and the ambient temperature—these two are the same. If not define what is what ? have gradually decreased. Figure 5 shows thea profile perspective-of-of the green roof whilst . Figure 6 shows the temperature evolution profile in the green roof and in the insulated room.



Figure 5: Perspective view of the green roof

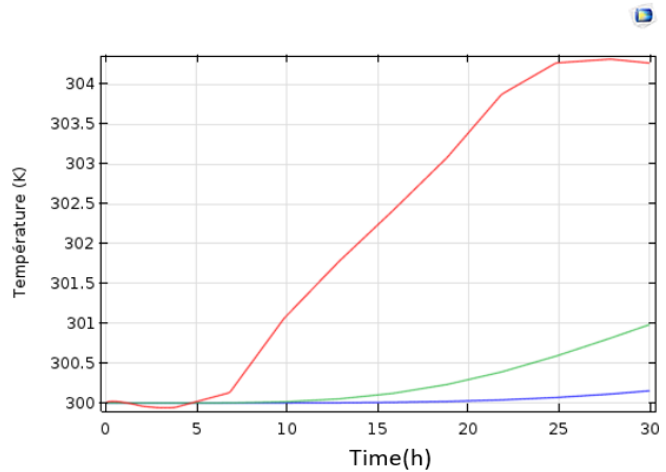


Figure 6 : temperature profile in the green slab and in the insulated room

The difference in evolution of the temperatures of three different environments (ambient temperature, room temperature, slab temperature, plant layer temperature) is represented in figure 7. Define what is ambient temperature ?

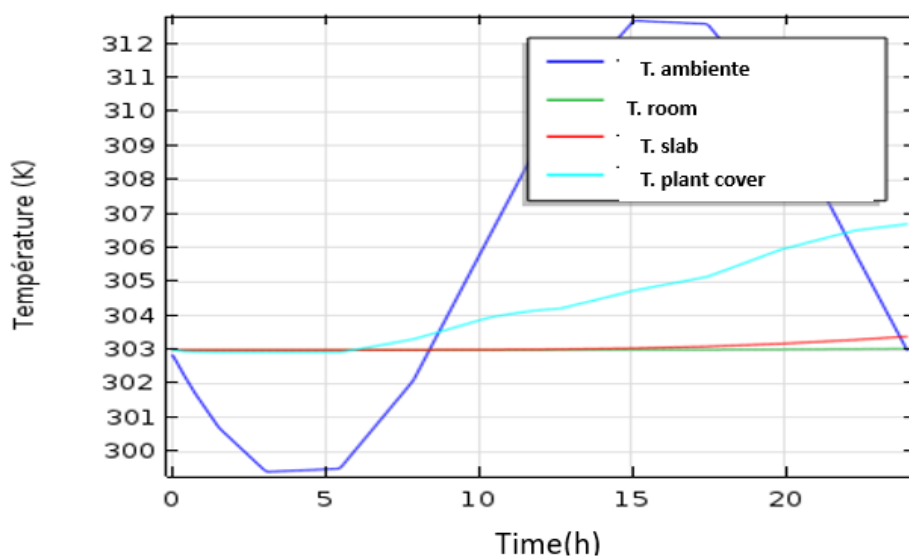


Figure7: Temperature Distribution within the room point graph

### 3.3- ~~Room and slab Evolution of the temperature in the bare slab and in the room~~

In the case of the bare slab, its temperature rises to 52°C in 18 hours, compared to an ambient temperature of around 29.5°C. The temperature of the slab decreases to 49°C in 24 hours, while the ambient temperature rises to 34°C, compared to 28 to 30°C, which is the comfortable temperature in the context of hot and dry countries, leading to a gap of +7°C Madiana HAZOUME[9]. This temperature is significantly higher than that of the green vegetated roof, which is 27.25°C. ~~We can conclude that t~~The bare slab allows for greater thermal flow compared to the green vegetated terrace roof. It provides less thermal comfort for the occupant in the habitat compared to the vegetated roof. Figure 8 shows a perspective view of the bare slab roof. Figure 9 shows the temperature evolution profile in the bare slab roof and in the room.



Figure 8: Perspective view of the bare slab roof

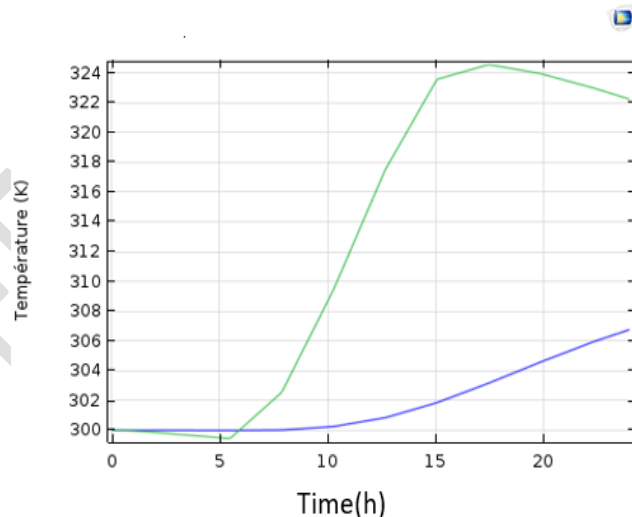


Figure 9: Temperature profile for the bare slab roof and the room

Check y axis temperature UNIT ?

### 3.4- ~~Evolution of the temperature in the metal roof plate and in the part~~

In the case of the sheet metal, its temperature rises to 56°C in 18 hours, against an ambient temperature of around 31°C. The temperature of the sheet metal decreases to 49°C in 24 hours, and the ambient temperature rises to 35°C compared to 28 to 30°C, which is the comfort temperature in the context of hot and dry countries, resulting in a +8°C difference, according to Madiana HAZOUME. This temperature is significantly higher than that of the bare slab roof, which is at 34°C. We can conclude

that the sheet metal allows more thermal flow compared to the bare slab roof. The sheet metal roof does not guarantee thermal comfort for the occupant compared to the slab and green roof. Figure 10 shows the perspective of the sheet metal roof. Figure 11 shows the profile of the temperature evolution in the sheet metal and in the room.



Figure 10: Perspective view of the sheet metal roof

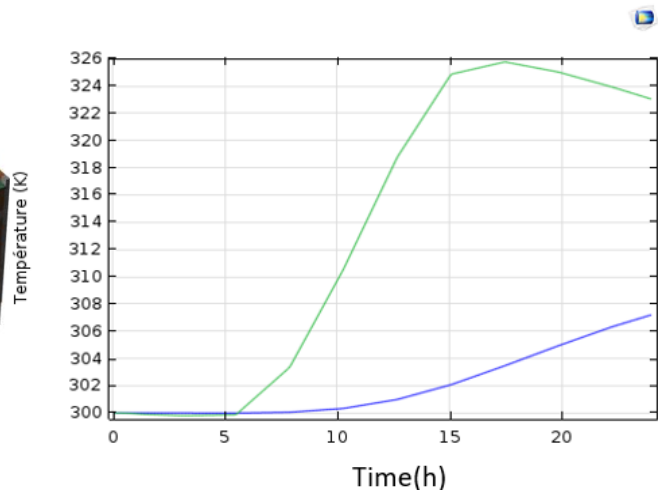


Figure 11: Temperature profile in the sheet and in the room

Room temperature in the metal roof and slab is 306 ? what both same ? what is the unit of temperature ? C<sup>0</sup> or F<sup>0</sup>

Referring to the principle of heat exchange, the higher the internal temperature of a room, the greater the thermal flow into the side that room, and vice versa. The results of the modeling using with the Comsol software allow us to conclude that among these three types of roofs, the green roof guarantees good thermal comfort compared to the other types of roofs (slab, metal). Therefore, the green roof improves the thermal comfort for the occupant in the habitat.

### 3.5- Advantages of green roofs on thermal comfort in the Sahelian zone.

It is a factor in the preservation of biodiversity, environmental recovery, and ecological continuity in the Sahelian zone. This sentence is conceptually wrong. What is the connection of green roof to biodiversity ? A green roof facilitates It meets the need for high-quality environment through thermal insulation of the room buildings, hygrometric comfort, acoustic comfort, and sanitary air quality due to its their capacity for CO2

absorption and O<sub>2</sub> contribution from the air by plants owing to the phenomenon of photosynthesis. The green roof covering an area of 1.5 m<sup>2</sup> fulfills the oxygen needs of an adult person ~~man~~ or man or woman?. Figure 12 shows the production and absorption of (CO<sub>2</sub>, O<sub>2</sub>) by humans and plants.

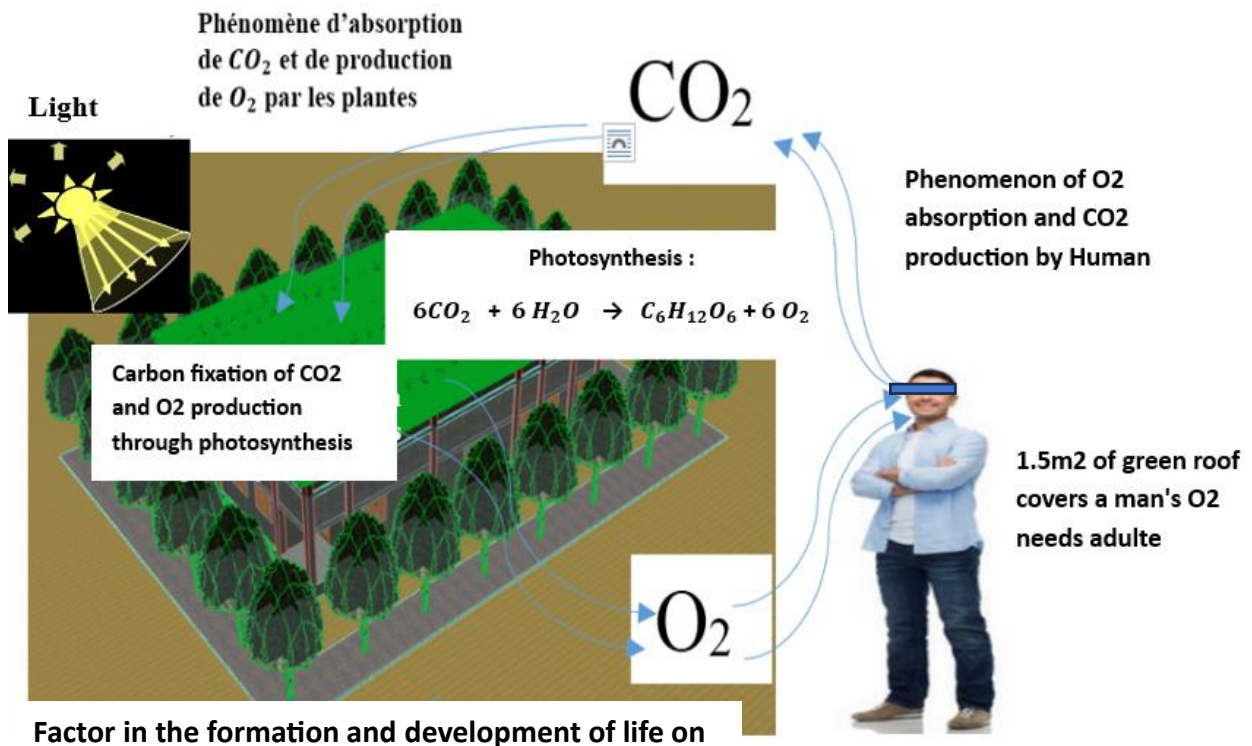


Figure 12: Production and absorption of (CO<sub>2</sub>, O<sub>2</sub>) by humans and plants

Show CO<sub>2</sub> absorption figure too. Then reader can compare the carbon balance

## CONCLUSION

The analysis of temperature differential shows We note that green roofs ensure better thermal comfort in housing than other two types of roofs namely, metal and concrete. They help preserve biodiversity and ecological continuity. From a high environmental quality perspective, green roofs help maintain freshness in the building's environment and contribute to the release of phenomenon of photosynthesis through significant and the absorption of CO<sub>2</sub> . oxygen production for respiration. Not to mention that fFrom an economic standpoint, green roofs reduce energy costs as artificial temperature reduction is not required. On the other hand, the roof and maintenance expenses are high as slab needs to be water proofed to reduce leak and plant maintenance cost (watering, adding nutrients) is high. of waterproofing systems. They

provide many benefits, and their maintenance can be a source of employment for young people. Also, country has a water shortage then how to find water for roof plants ? Taking all factos into consideration, Hence there are definite advantages for the need to promoting e-the construction of houses with green roofs to support demographic balance in the Sahelian region.

Other comments : Green roof means grass, bushes or large trees ? Better to test roof containing above material re heat transfer. worthy to try out heat exchange for a roof containing dead vegetation material. This does not have high maintenance cost compared to green material. Also, heat transfer for a building with clay roof.

In the explanation for green roof, show that evapotranspiration needs energy which is taken from the roof thus reducing amount of heat generated on roof top. Need to show calculation of energy balance (in absolute terms) for green, metal and slab roof.

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