Contribution of Semi-Arid Forests to the Climate System

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Outline

- Background
- Objectives
- Method
- Results and interpretation
- Critique of their Interpretation

Background

Desertification

- Many semi-arid regions have underwent large-scale desertification over the past several decades.
- In the future, more regions including central Europe, the Mediterranean and Central America will suffer the risk of drought.
- Understanding the ecosystem function in dry environment is crucial in order to assess potential responses and make informed management decisions.

Carbon Sequestration

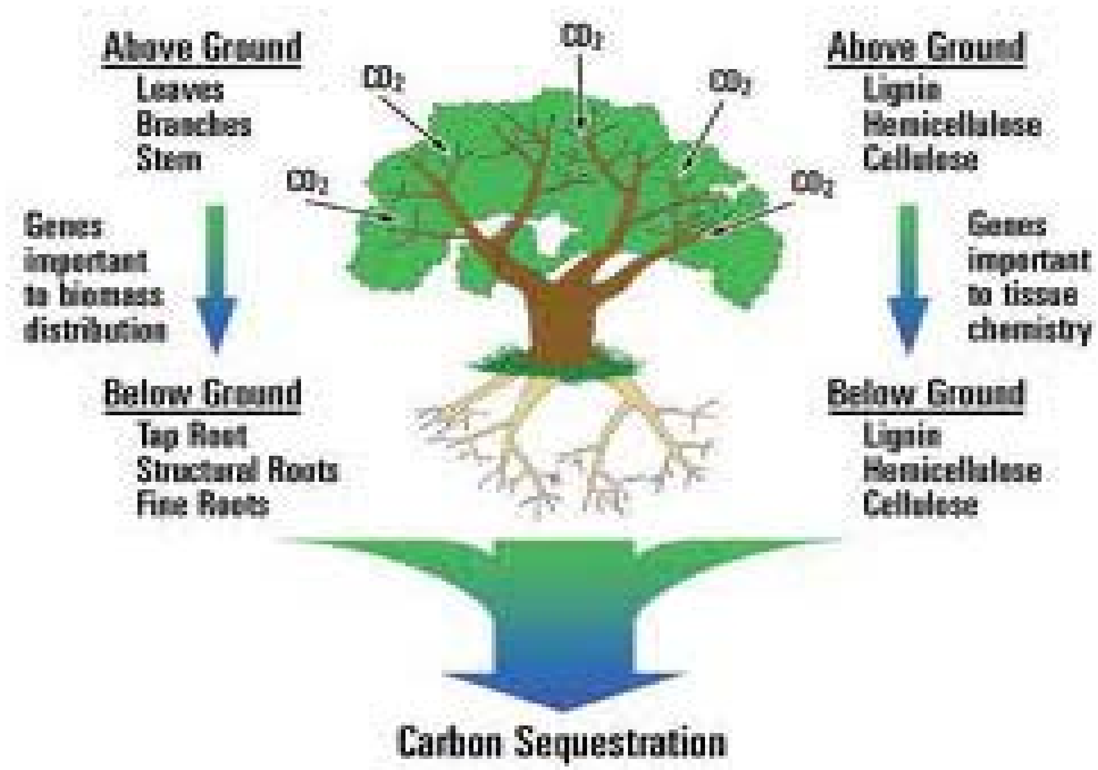


Fig.1.1 The process of carbon sequestration

Albedo Energy Balance

$$R_n = S\downarrow(1-\alpha) + L\downarrow - L\uparrow$$

R_n: Net radiation

$S\downarrow$: Incoming solar radiation

α: The ratio of the reflected solar radiation to the incoming solar radiation

$L\uparrow$: Upwelling long-wave radiation

$L\downarrow$: Downwelling long-wave radiation

Objectives

- **The time needed to balance the radiative forcing (RF) brought by albedo change (and long-wave radiation) and by carbon sequestration in the studied site**
- **The estimation of the influence caused by desertification in the semi-arid region**

Method

- Site Information
- Experimental Design
- Data Analysis

Site

Location	Area	Vegetation	Climate	Data Source	Year included
Southern Israel	2800ha	Pine Forest	Semi-arid	Flux Network	2000-2009

Table.1. The general information of the studied site

Fig.2.2 A photograph of the Yatir Site and its environs

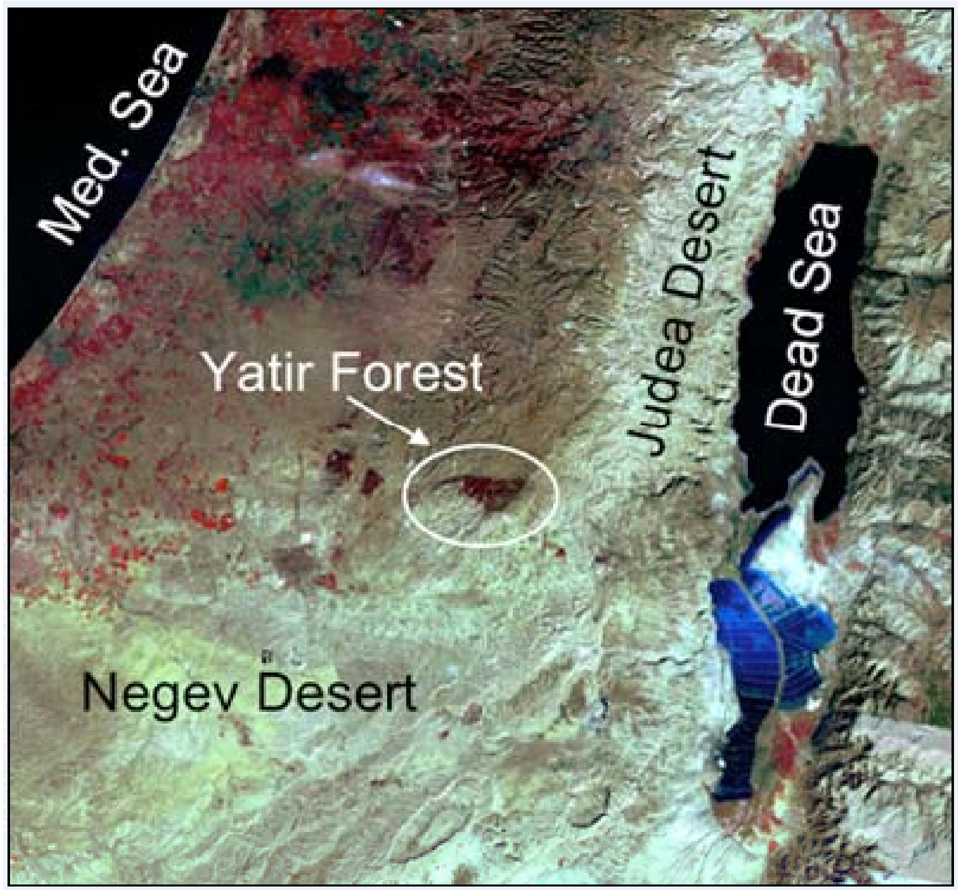


Fig.3.3 The satellite image of Yatir and its surrounding

(from http://www.fluxnet.ornl.gov/fluxnet/graphics.cfm)

Pine forest	*GPP* (g C m^{-2})	R_e (g C m^{-2})	*NEE* (g C m^{-2})	*NEE/GPP*
European (Carboeurope)	1142	944	200	0.17
Global (FluxNet)	1540	1280	260	0.17
Semi-arid (Yatir)	820	600	220	0.27

Table.2. Indicators of carbon use efficiency in pine forests: GPP, Re and NEE of carbon for the 12 European pine forest sites, for the entire global Fluxnet network and for semi-arid forest Yatir.

GPP: Gross Primary Productivity
NEE: Net Ecosystem CO_2 Exchange
R_e: Autotrophic Respiration

$$GPP = NEE + R_e$$

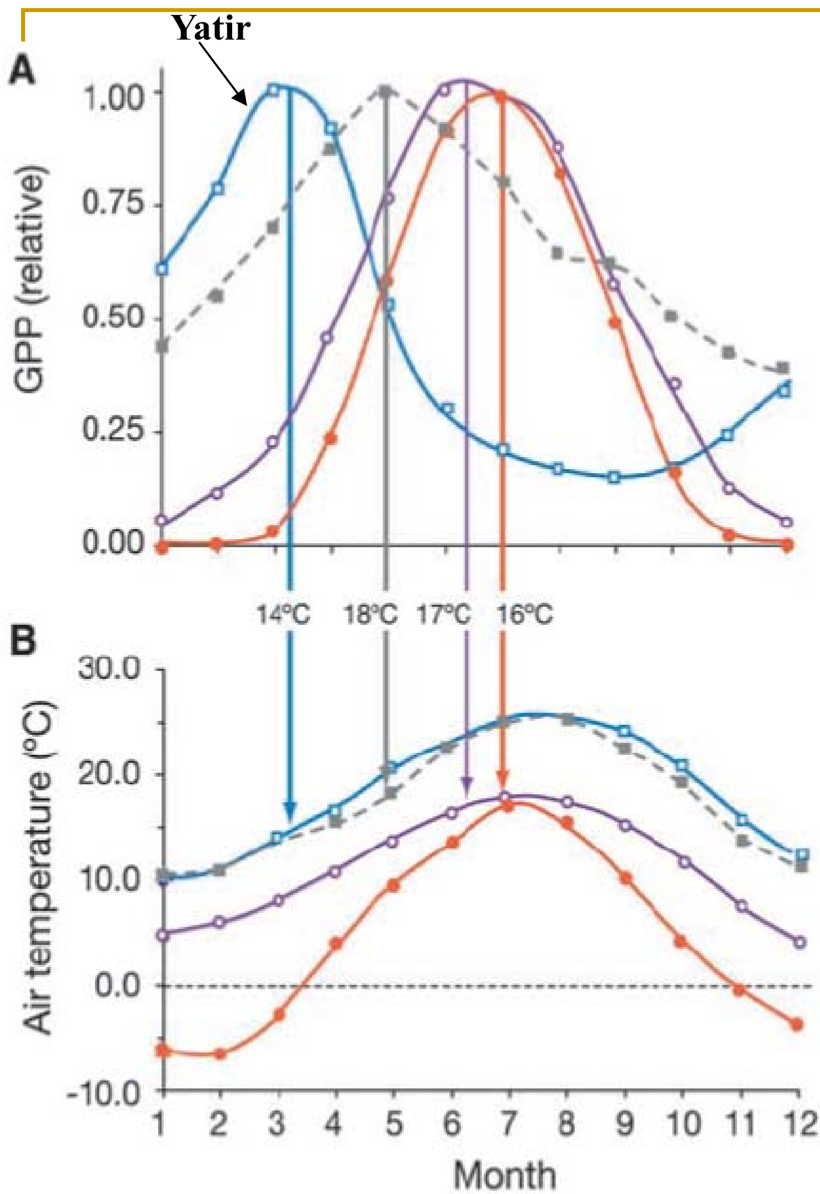


Figure.3(A).Annual pattern in GPP/GPP_{max}

Figure.3(B). Air Temperature in 4 representative European pine forest sites :Yatir, Israel (blue); El Salar, Spain (Gray); Brasschaat, Belgium (Purple); and Hyytiala, Finland (orange).

- **Due to the adjustment in timing and productivity of forest carbon uptake, seasonal drought may not cause the forests lose massive carbon.**

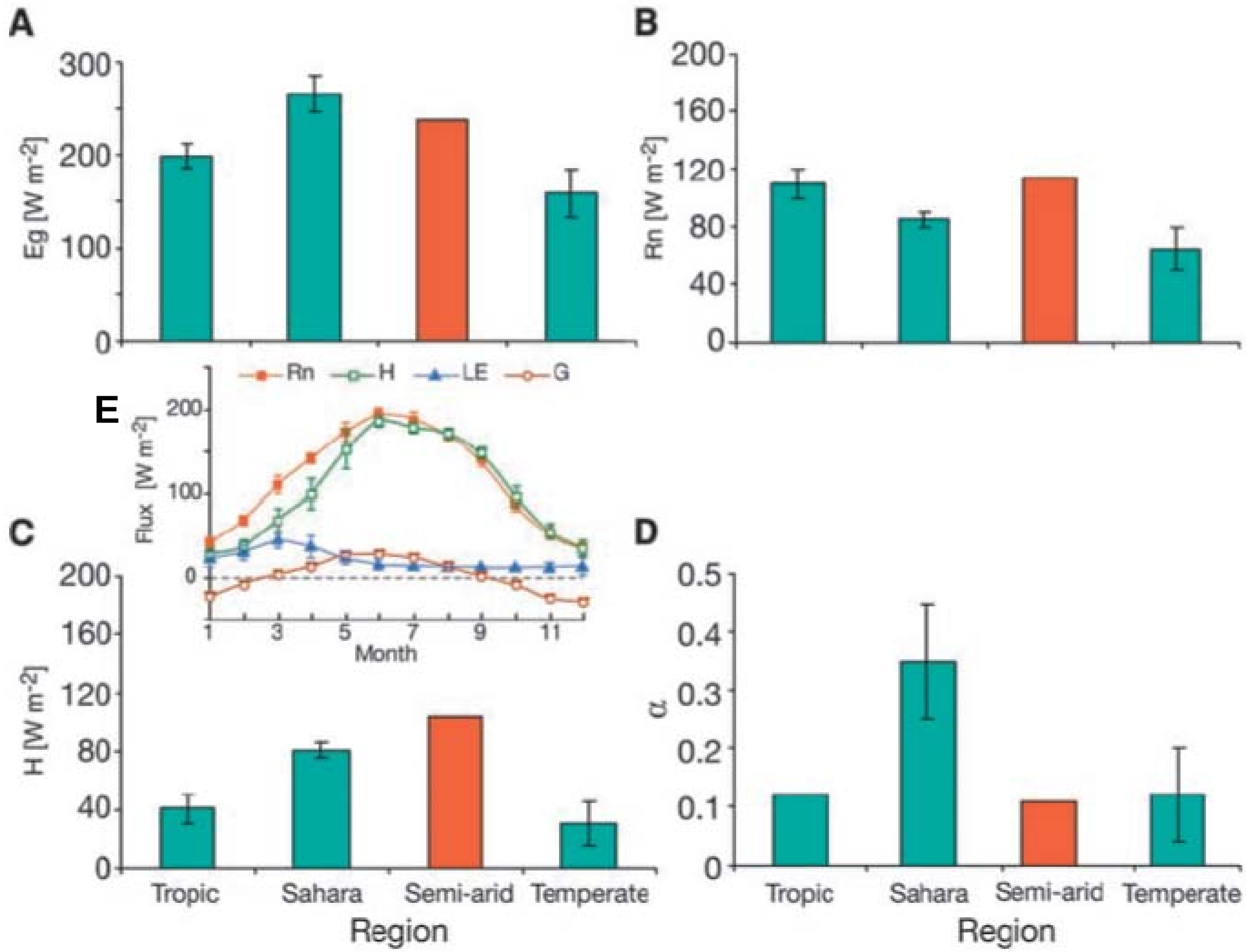


Figure.4.Annual means of energy flux components in forests (except Sahara) in globally representative regions: (A) Eg, (B) Rn, (C) H, and (D) surface albedo, α.

Variable	Forest		Shrubland
Global radiation (E_g, W m^{-2})	238		238
Albedo (unit-less)	0.11	0.1	0.21
Net solar radiation (S_n, W m^{-2})	212	24	188
Net longwave radiation (L_n, W m^{-2})	–96	25	–121
Net radiation ($R_n = S_n + L_n$, W m^{-2})	115		67
Skin temperature (°C)	19		24*

Table.3.Annual mean values (6 years) in the semi-arid forest (Yatir) and in the shrubland background

- **The low-cloud high-radiation environment results in a large increase in surface radiation load.**
- **This relatively large short-wave albedo effect is essentially doubled by a long-wave radiation effect.**

Experimental Design

Using albedo-derived short-wave RF of the forest, δ_s=24W/m^2, together with the calculated RF associated with carbon sequestration, through equations(1) and (2)to calculate the time required to achieve the balance.

$$\triangle C_T = 2(M_c / M_a) m_a \triangle C / C_0 \qquad (1)$$

$\triangle C_T$: terrestrial carbon stock change

M_c: molecular masses of carbon （12.0107kg/kmol）

M_a: molecular masses of dry air （28.966kg/kmol）

m_a: mass of the atmosphere （5.1×10^{18}kg）

$$F = 5.35 \ln(1 + \triangle C / C_0) \qquad (2)$$

F: Local instantaneous shortwave radiative forcing due to surface albedo change

$\triangle C$: the change of CO_2 concentration

C_0: the reference atmospheric CO_2 concentration (370p.p.m)

- **The time required for a semi-arid forest to achieve balance between the surface positive RF and the carbon sequestration negative RF is based on equation (3):**

$$y=(RF_{surface}\times\kappa\times C_0)/(A_E\times NEE\times\eta\times\xi) \quad (3)$$

$RF_{surface}$: the albedo or the combined long-wave effect

A_E: the earth surface area (m^2) i.e. $5.1\times10^{14} m^2$

κ:converts p.p.m CO_2 to kg C

C_0: the reference atmospheric CO_2 concentration(370p.p.m)

η:the CO_2 radiative forcing efficiency(W/m^2)

ξ:the airborne fraction

NEE: the observed annual net carbon uptake of the semi-arid forest (kg C m^{-2} $year^{-1}$)

- **Considering short-wave and long-wave radiation effects, the site need 80 years to achieve the balance.**

- **Estimation of the effect by the long term desertification trend in the semi-arid region**

$$RF_{S+L}(y)=A(y)(\delta\alpha \times E_g+\delta_L)/A_E \quad (4)$$

A(y): Annually degraded area accumulated to year y

A_E: Earth surface area ($5.1\times10^{14}m^2$)

δ_α: 0.1

E_g: 240 W/m^2

δ_L: 25W/m^2

$$RF_{CO2}(y)=\eta \times Ln(1+C(y)/C_0) \quad (5)$$

η: CO_2 radiative forcing efficiency (5.35 W/m^2)

C_0: Reference CO_2 concentration (360ppm)

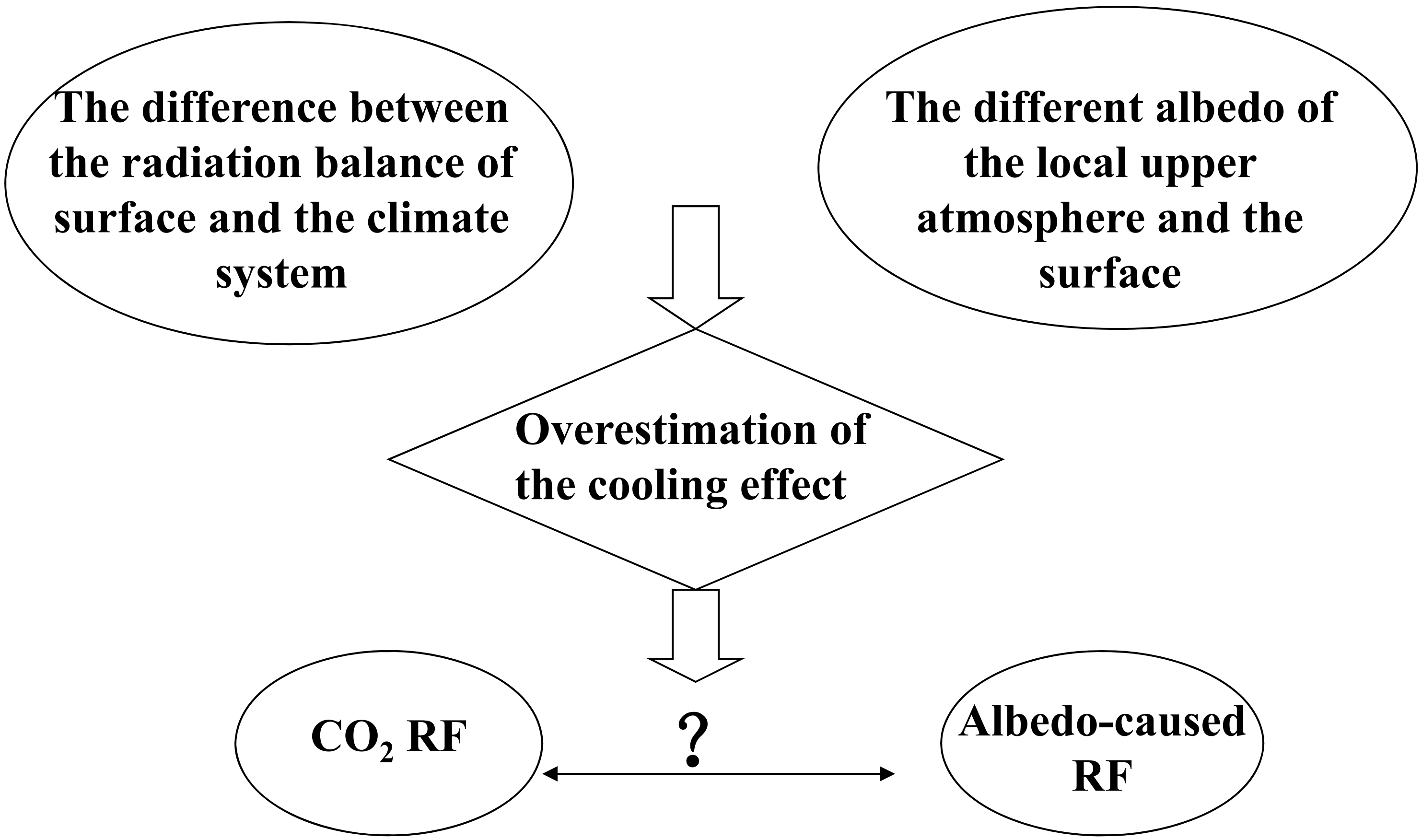
C(y) : Total CO_2 emitted over y years

Results and Interpretation

- RF_{S+L}=-0.145W/m^2, RF_{CO2}=+0.006W/m^2, and the total desertification in the semi-arid regions has a combined RF of about -0.14W/m^2.
- That is to say, the desertification has a cooling effect.

Critique of the Interpretation

By Xuhui Lee, 2010



By Stefan Leu(2010)

- **The range of application of the results for other regions which undergo the desertification is narrowed.**
- **The difference between the spectral properties of infrared radiation reflected from green vegetation and exposed soil.**
- **The different functions of the pine forests and common dryland ecosystems (open woodlands, savannas, and grasslands).**