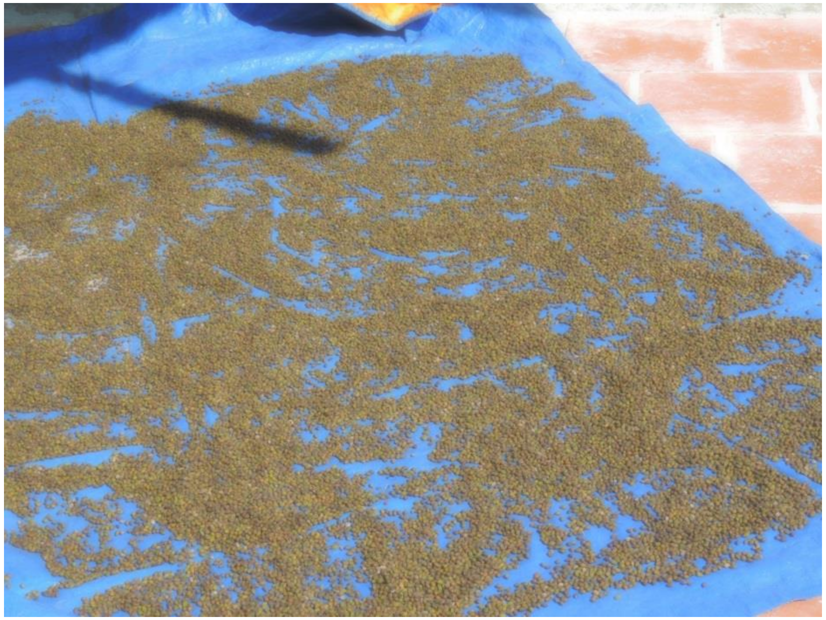
Drying in developing countries : technical, energy, environmental, economic and social aspects.

Application of West Africa case

Hélène Desmorieux
University of Claude Bernard Lyon 1

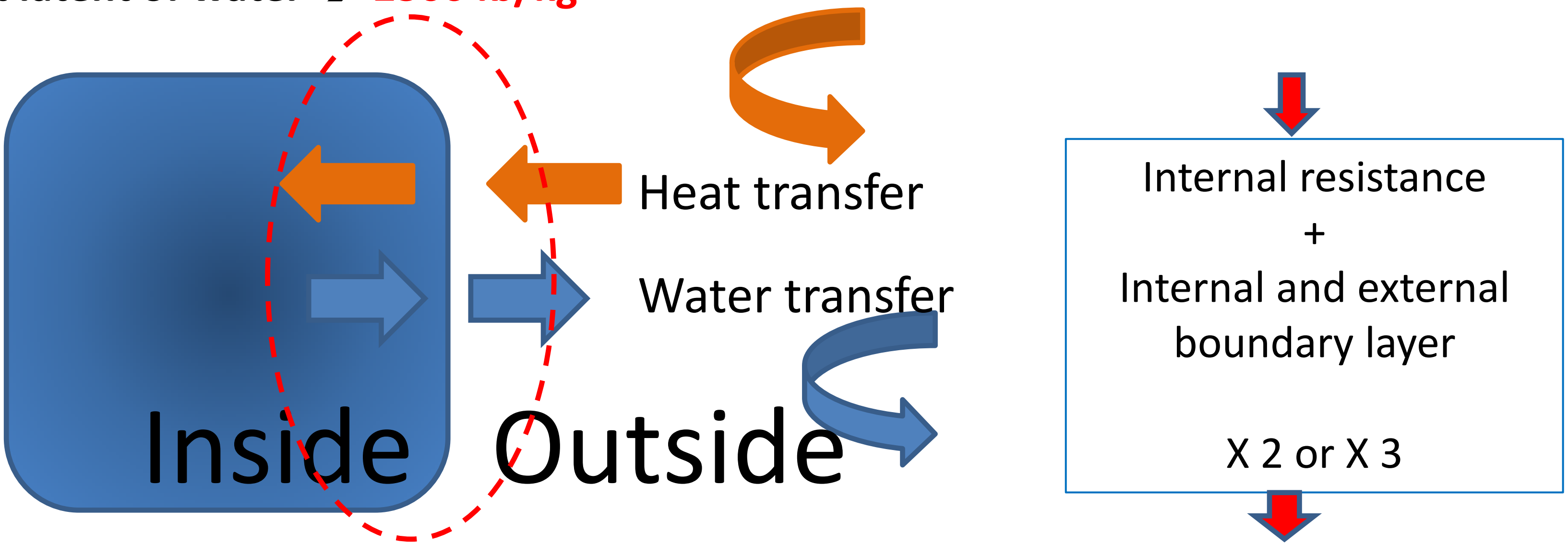
- **Drying**
- **Subsaharian context**
- **Litterature**
- **Survey and results**
  Criteria to take into account
- **Local knowledge and know how**

Most of food products need a step of drying



Why drying is linked to energy?

- Drying consists in removing water (solvant) from a product (liquid or solid)
- **Heat latent of water ➔ 2300 kJ/kg**



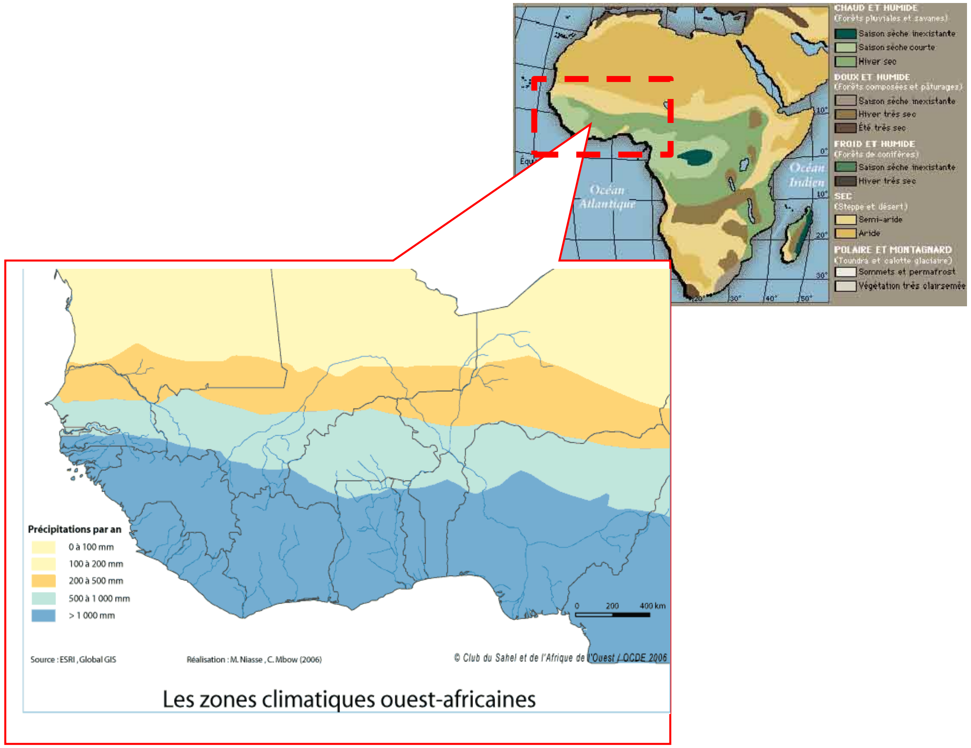
- Spray drying ➔ **5000 kJ/kg**
- Tunnel dryer ➔ **4000 kJ/kg**
  (le monde alimentaire, 2001)
- High quantity of energy is needed to dry

The problematic of Drying and Dryer in subsaharian zone

- Subsaharian Zone

  From equator to 20°//
  - **2 seasons**
  - **Humid equatorial Climate**
  - **Tropical Climate**
  - **Soudano Sahelien Climat**

- Drying
  - none industrial : <2T/cycle



- **Many projects $**

- **Only a few of dryers are used**

- **Most of them are transformed and adapted**

The problematic of Drying and Dryer in subsaharian zone

Products goals

- **Food families**
  Vegetables, rice, tomatoes, onions,… Cassava, wheat, Mil…
- **To sale excess**
  Tomatoes, onions, chili,
- **Economic activity**
  coffee, cacao, cotton, rice, coffee, fruits mangoes, bananas, pineapple
  - ➢ Local market
  - ➢ Exportation
  - ➢ Cultures

user needs

- **To provide dry product with better quality**
  - ➢ Better sale
  - ➢ Better preservation
  - ➢ Export
- **Higher drying efficiency, shorter drying time when air is too humid**
- **Dry in large quantity to sale more increase economic activity**
- **➔ need solutions without a high investment**

Constat

- **Many studies to improve drying (quality, energy accessibility, - technology)**

- **Researchers : 1990-2010 : Most transfer of technology of dryer**

consider the criteria of good energy efficiency

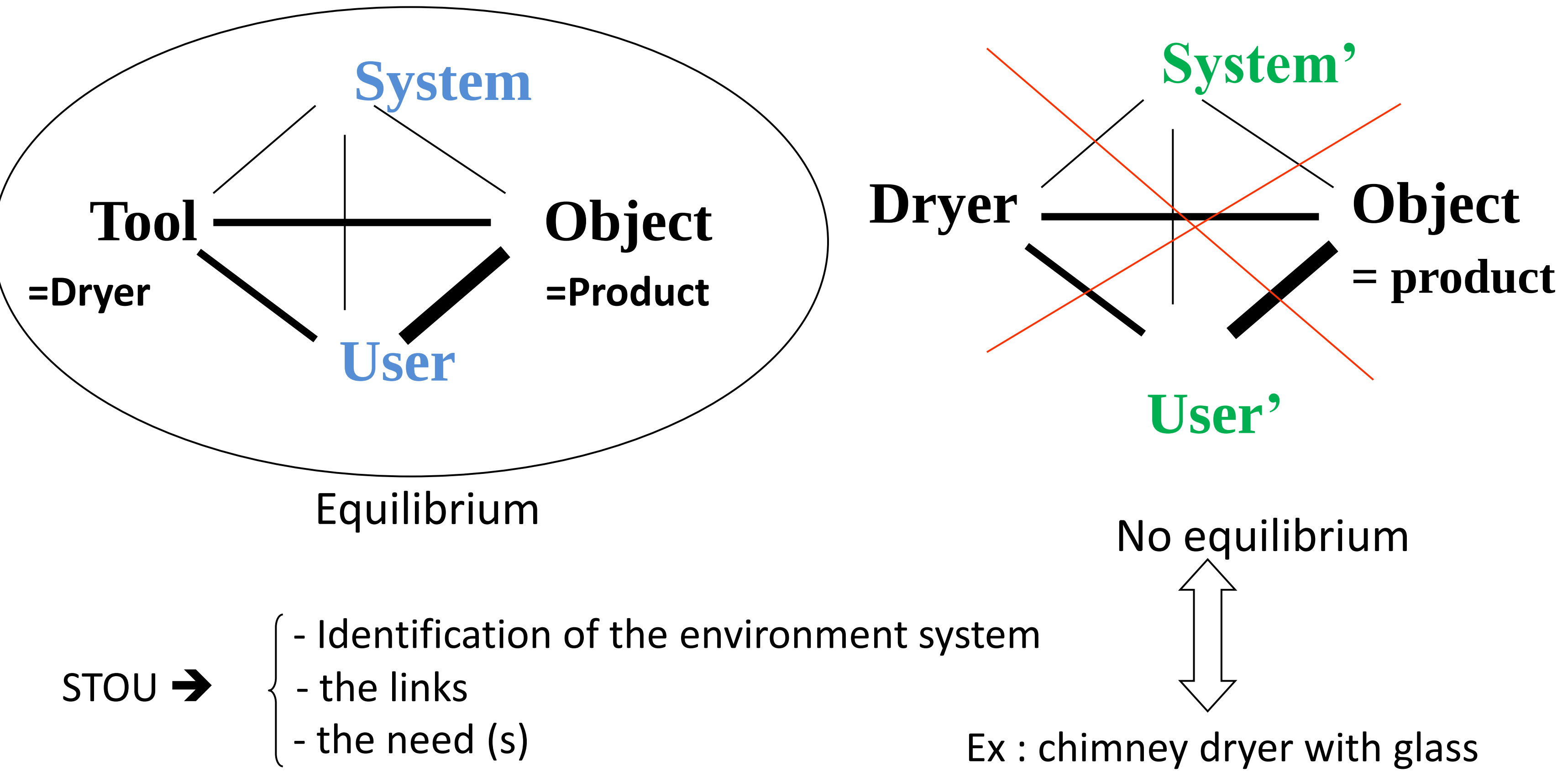
- **Users : preserve their food, economic benefits**

- **On the local universities : new dryers, build on university or imported**

- **On the field : new dryers not used**

- **Not used → Why?**

S T O U analysis of the problematic of transfer of technology (Galaretta, CNES)

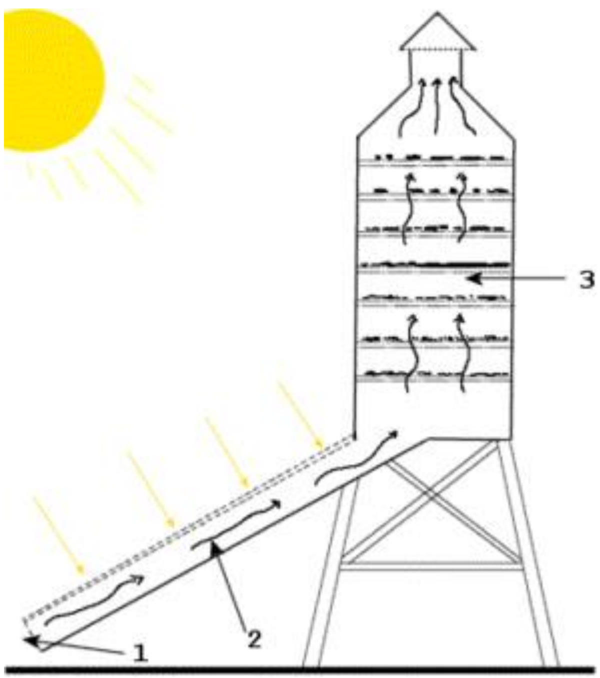


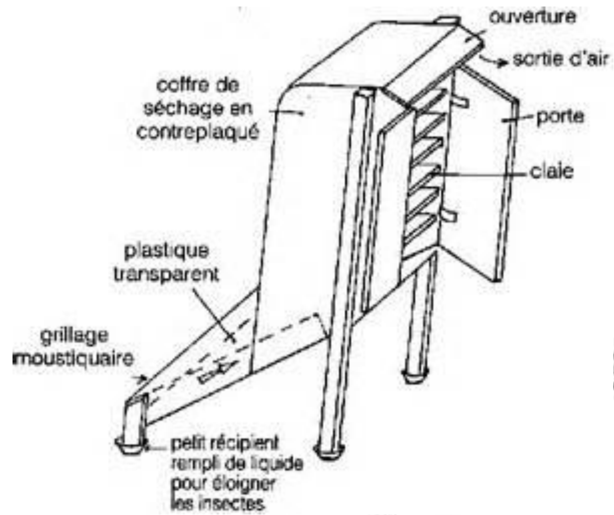
STOU ➔
- Identification of the environment system
- the links
- the need (s)

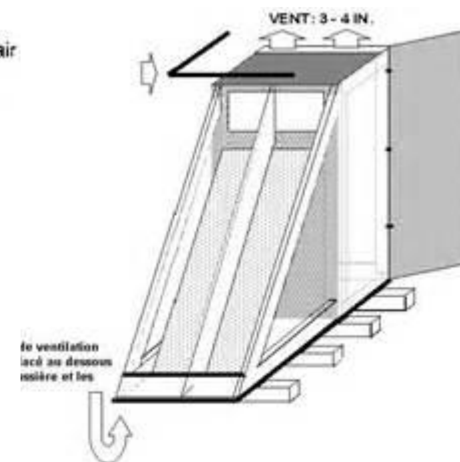
Necessity to consider the system

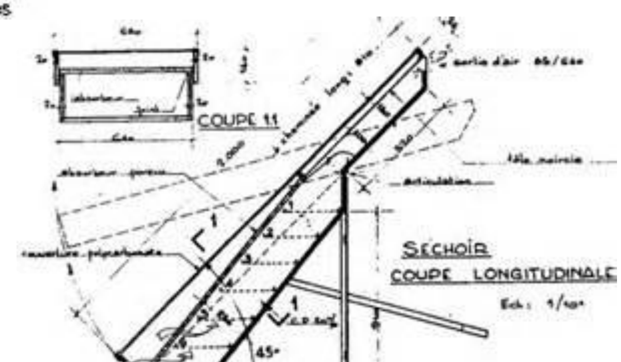
Typical studied dryer : chimney dryer

- Good energy efficiency for low capacity
- Broken glass
- Clay has to be removed









Caracterizing and classification criteria for dryers

- **From litterature review ➔ 5 families of criteria**

- **manufacturing criteria**: materials, dimensions, load, used power…

- **performance criteria** in terms of material and energy balance, performance of solar collectors, of combustion..., environmental impact.

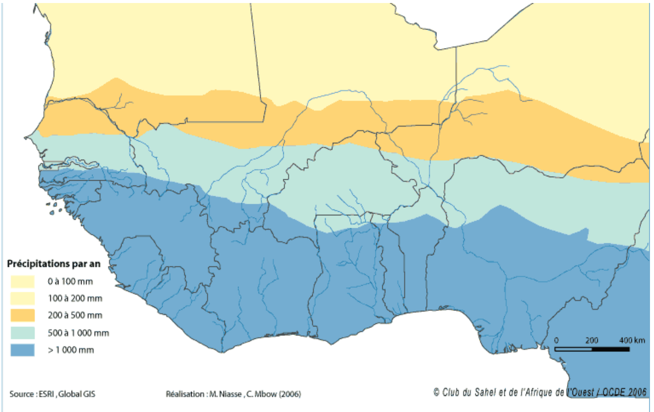
- **product criteria** : initial and final water content, sensory and nutritional qualities, capacity for rehydration, homogeneity…

- **economic criteria**: cost of the investment, operating costs, added value to the dry product

- **ergonomic and functional criteria**: level of technicality and availability of operators, ergonomics of the tasks (normal use, cleaning, maintenance), adaptation to the local climate.

Survey

- Togo + Benin + Burkina Faso
- 140 dryer users
- Face to face and phone interviews

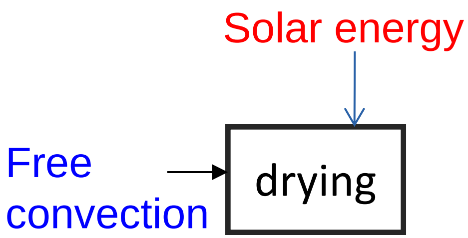


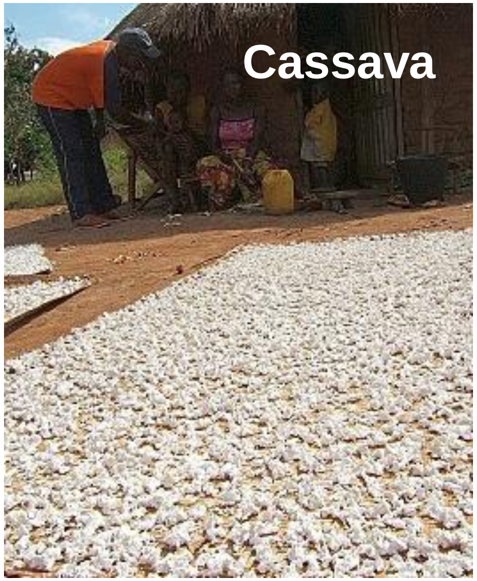
Les zones climatiques ouest-africaines

- Aims :
  - Caracterisation of the dryers and the drying
  - Why do they use this type of dryer
  - Satisfied?
  - Needs?
  - Are there criteria to be added to design sustainable dryers?

Used dryers

Sun drying : 85% of used dryers!





Direct and indirect solar dryers

Solar energy → Drying ← Indirect solar energy

Free convection → Drying

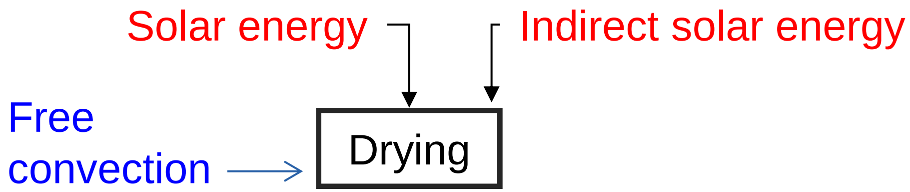
> 500 ex

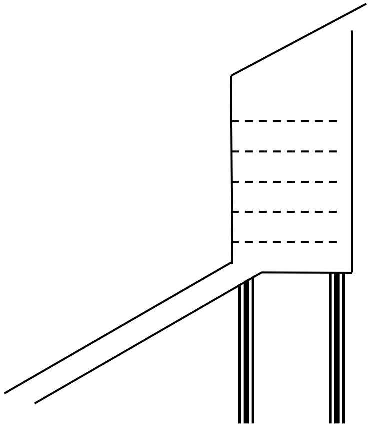
Subsidized

Low investment cost
Protection against direct solar radiation

Very low drying

Direct or indirect solar dryers: Chimney dryers





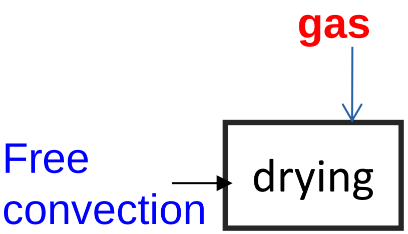
Many studies

- Optimisation of energy efficiency
- Local material: wood, stone, local isolated mat.

- Too complex technology for ..
- Limited capacity of dry product
- Too slow drying

But not used on the field

Costly energy : Gas dryers



Atesta dryer

Several layer
24 to 30 hours

High temperture
Local material

Irregular temperature control
Gas failure

No renewable energy, largely used on the field

CIRAD-Montpellier
CEAS – Burkina

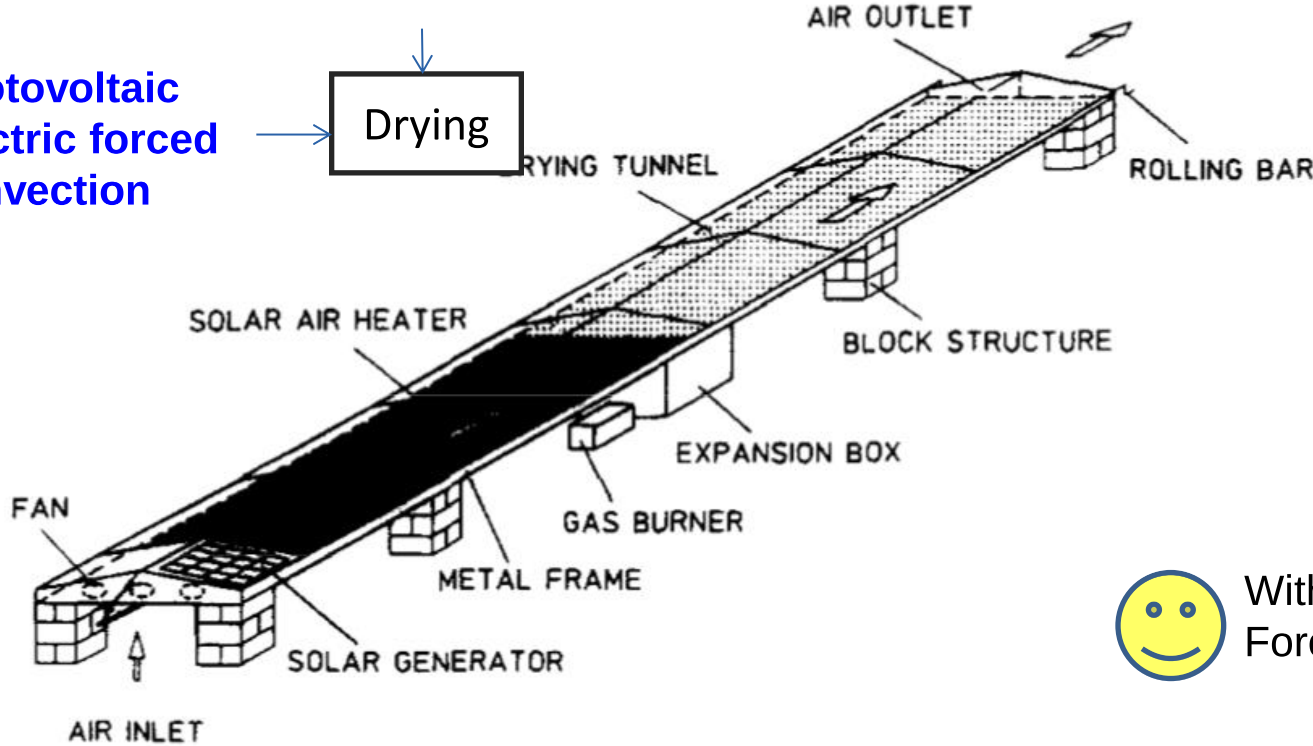
Hybrid dryers : gas + solar

Solar energy + gas

photovoltaic electric forced convection

Drying

Geho or Hohenheim dryer type

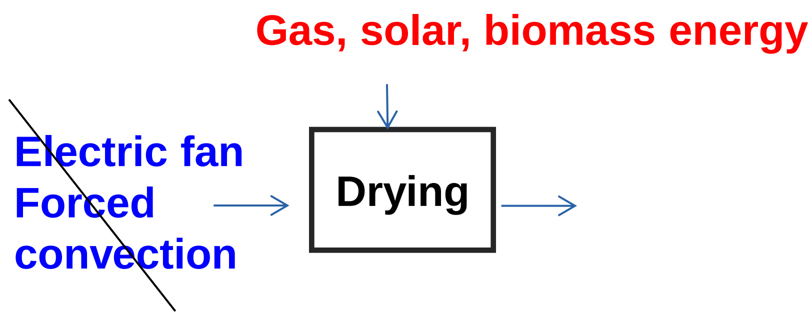


With or without gas
Forced convection

Large area on the ground

At the university of Hanoi, but no more used

Hohenheim University, germany
Esper, A., Mühlbauer, W., 1996



- No electric fan, no turbo ventilator :

- not limited by the cost of energy

But :

- high investment

+

- higher failure risk due to irregularity electricity supply – energy supplies not reliable

electricity fail of 1 hour to 10 hours

+

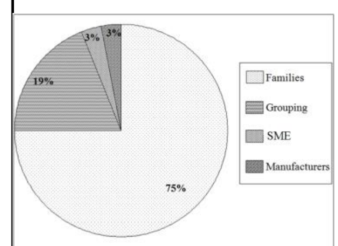
- need for maintenance.

=

➔ most used dryers, on the ground, run with free convection

➔Turbo ventilation used in Asia but not used in Africa
= energy from wind,

Criteria have to be taken into account

Information type	New criteria	Calculated criteria
Dryer specifications	number or trays mean materials used average used days per year	drying surface wet product mass per tray
Product specifications	other products dried in the same dryer mean sugars content / End use of product	dried product mass per cycle
Energy and mass balance		effective used energy per day Evaluated drying efficiency evaporated water mass per day
Environmental specifications	dryer advantages drawbacks as perceived by the users land space availability users type = families / groups / enterprises users organisation level geographical zone Regularity of all used energies supply energy cost and availability Distance from the material availability to the dryer	
Economic characteristics	investment capacity (costs the users can pay for the dryer) outlet market of the dried product Social network, possibility of subsidy	drying cost maintenance cost part of drying cost in turn-over

Criterium : accessibility of materials

« Local » material origin		Dryer types
Same village	⟺	Traditionnal sun dryers
Next town	⟺	Direct - indirect solar dryers
Same country	⟺	Dryers in enterprise

Local material =
f (distance to available material, dryer capacity)

Thermal and economic analysis typical dryers

Received solar energy per day (*E_s in kJ/j*) by the dryer

$$E_s = I\left(S_{dir} + S_{ind}\right)$$

Supply energy by butane gas

$$E_g = \frac{m_{g,cy}}{\Delta t_{cy}} \times PCI$$

Avalaible energy

$$E = E_s + E_g$$

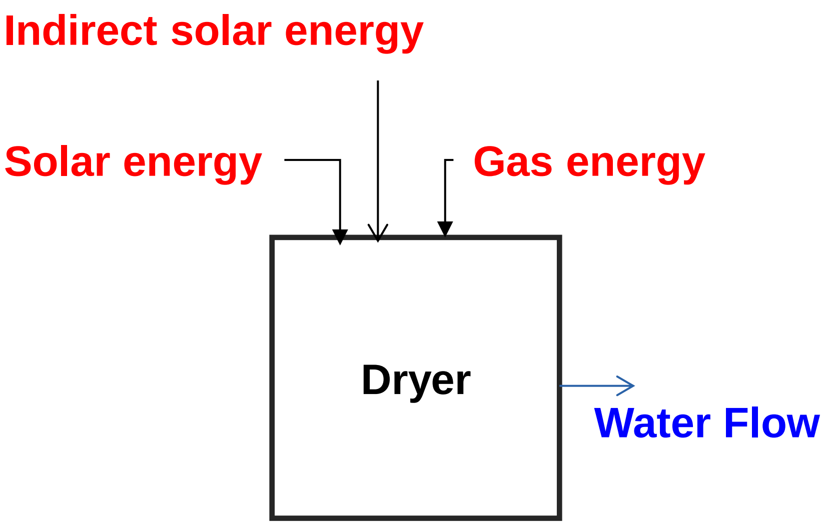
Energy for water evaporation

$$E_V = \frac{m_i}{\Delta t_{cy}}\left(\frac{X_f - X_i}{1 + X_i}\right) \times L_V$$

Energetic efficiency of the dryer :

$$\varepsilon = E_V / E$$

Heat and water balance




Sun drying


Sun drying


shell dryer


indirect cupbord

Thermal and economic analysis typical dryers

Investment cost

+ Capacity of dry product

+ Take into account the duration of use in the year

+ the average evaporated water flow

+ Maintenance cost

⇓

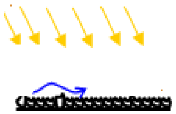
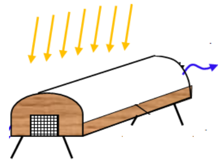
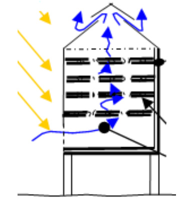
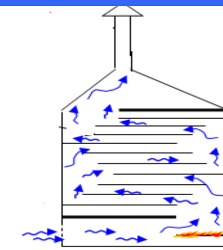
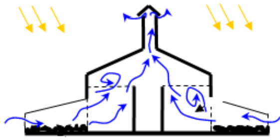
Cost and economic efficiency of the drying

Drying cost per kg of evaporated water per day

Gain/day (f CFA/d)

Thermal and economic analysis

Typical dryers

Dryer						
Products	Mais - corn	manioc	tomatoes	tomatoes	pineapple	rice
ε = (evaporated water) / (evaporable water)	8%	25%	19%	15%	36%	23%
Drying cost per kg evaporated water (f CFA /kg)	7	60	65	45	50	7
Gain per day PV_j (f CFA/d)	345	35350	-90	-235	48230	419090

Criteria : User types-Products types-Cost/m 2

Dryers types	Users and characteristics	Dryed products	Dryer Cost
Solar drying on a support : mat, cover, sheet steel table, road,	Families	Local consumption No fruits	Closed to zero
Direct and indirect solar drying	Families, groups	Local sale Export for crops No fruit for export	15 < cost < 80 €/m² of tray
Costly energy :gas or electricity	Enterprises	All products, fruits	100 < cost < 200 €/m² of tray
Mix drying: solar + gas or electricty + biomass			
forced convection ; Mix energy with solar		Little used	Above 100€/m² of tray
Photovoltaic		Little used	

Knowing criteria for choice

➔ choice method
➔ value of criteria depending to the system

The knowledge transfers

The direction of knowledge transfers

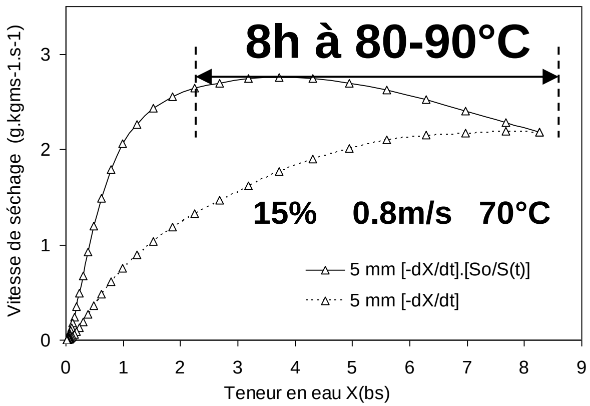
- North ⇔ South
- University ⇔ on the field even in developing countries
- Two examples :
  - mangoes drying at *too* high temperature
  - *Too* high thickness of Spirulina layer drying

Supply of know how, example 1 : mangoes drying

How we can learn from local users : two examples about drying

West Africa : 300 000 T/year

Several dryers



Litterature
T<60°C

On the field
T = 80-90°C during 6-8 hours

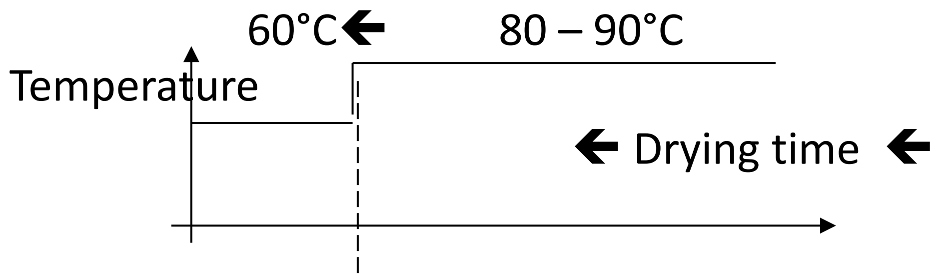
No first stage + high temp
➔ good quality

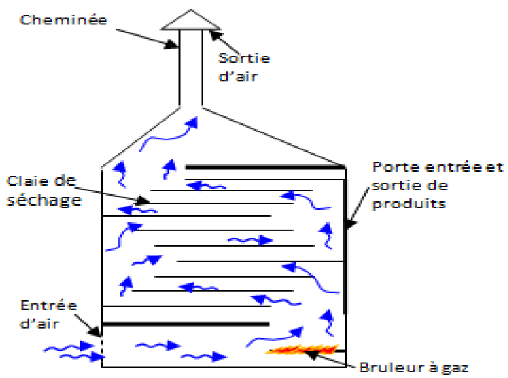
Formation of operators
Local + international network

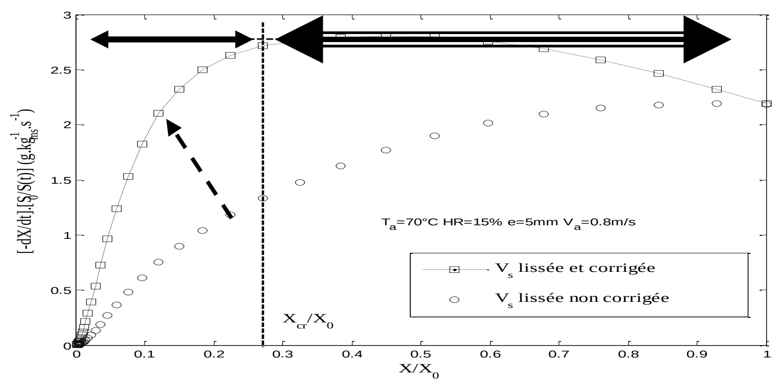
Drying rate with conditions chosen by producers
➔ shrinkage
➔ first stage appears
➔ High temperature during first stage

Taking into account the « know how » to understand mass transfer in food drying

Control of food mangoes by surface temperature







Understanding the under different condition traditionnal processes

➔ involve new knowledges

⬇

Lower energy consumption by temperature profil control during drying

Need :

Need drying model + control model

Need to bring knowledge to the dryer users :
=>water and heat transfers
=>what temperature and when?

- **Mangoes**
- **Tea**
- **…**
- **Example of maize drying in 2 places in Vietnam:**

Corn maize drying 1 in Thanh Hoa

T=80 =>T>100°C


Maize drying 2
in Thanh Hoa
T>130°C during all drying
Paid back p = 1year
150
200
100
250
50
300
0
°C

Supply of know how, example 2 : Spirulina drying

- Earthrise, cyanotech, ….

180000m2 in the Sonoran desert, Earthrise

Chad

Spray drying in west California

Convective hot air drying in France

Some dryed Spirulina

Spirulina Classical process

100% Spirulina

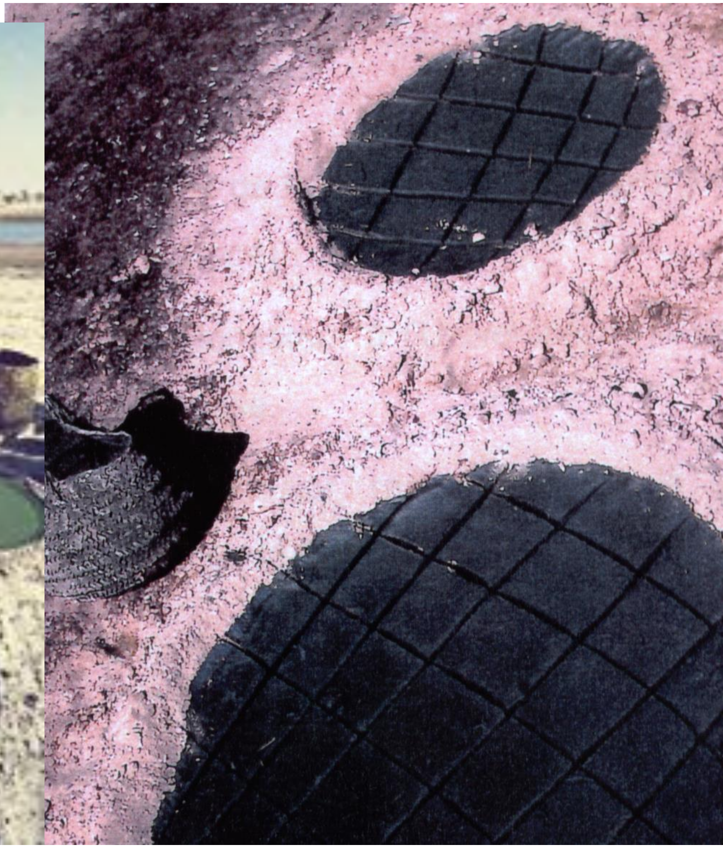
Maximal 2 mm thick

Drying over sand in Chad

Dihé, 5 mm thick → ?

40 tons/year

Using the capillarity of the sand



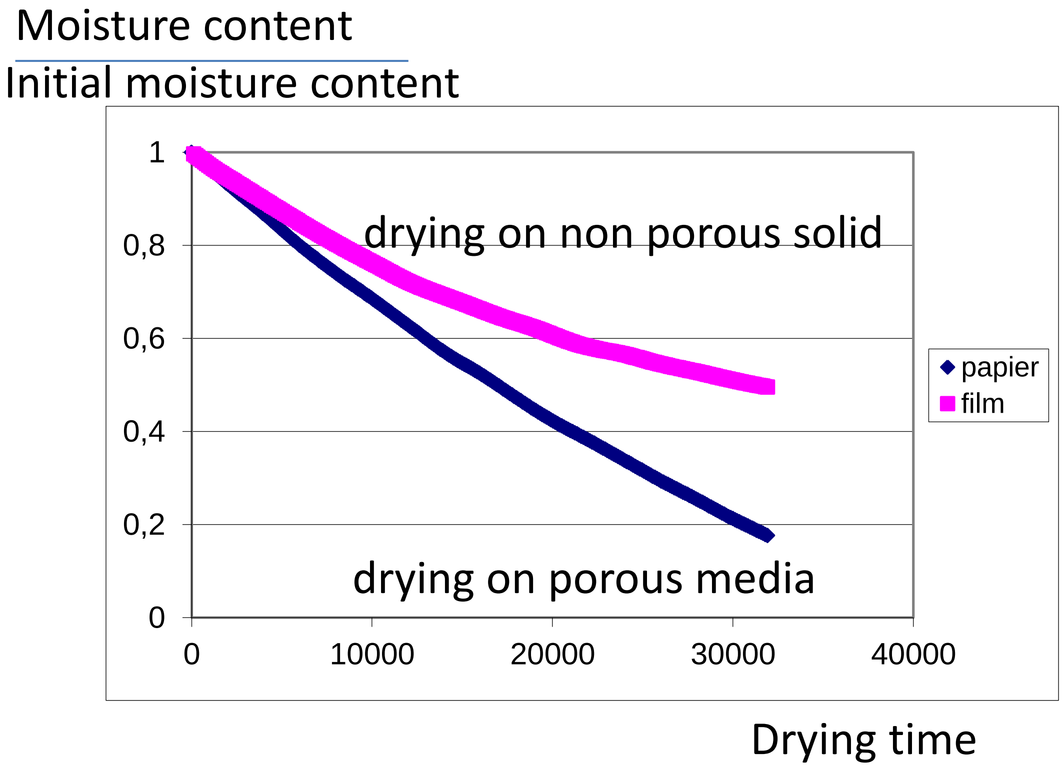
Intensification of drying by capillarity

Understanding the traditionnal method ➔ allow developping a new process

Product to be dry + porous media

$\Rightarrow$ **Drying + capillarity succion**

$\Rightarrow$ **increase the drying rate**



Conclusion

- Design has to be distributed between specialists in engineering, economic….and users
- Need of users have to be identified with the users
- Motivations of all the actors have to be identified : even politic, social, economic….
- To better and quick adaptation: necessity to take into account the local knowledge
- Knowledge transfers has not only one direction

Thanks to

Tchamye Boroze, LES Lomé, Togo
Kossi Napo, LES Lomé, Togo
Jean Michel Meot, Cirad, Montpellier

Didier Lecomte, ITC, USTH

Minh Ha Duong, USTH, Hanoi
Trung Vu Truong, USTH, Hanoi