North-South Slopes - Converting Semiarid Dryland into Cultivable Land- International Collaboration

Preproposal

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This preproposal provides an outline for subsequent proposals that will be used by our international collaborators to address their research agendas and specific implementation in their respective countries.

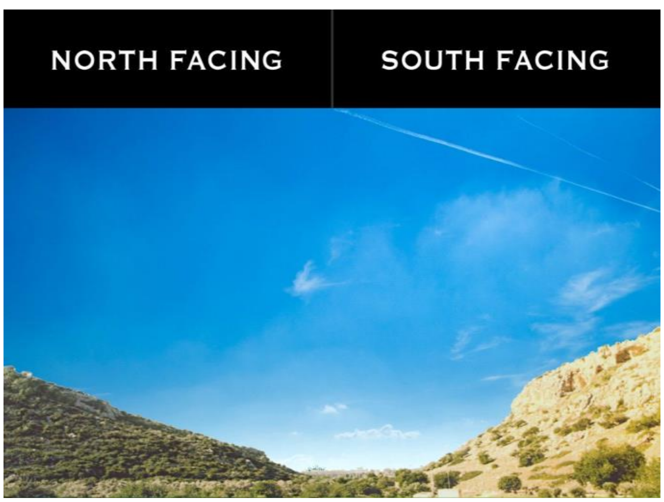
Pre-Proposal Phase I

Phase I of our Research for the ReSlope program will be for changing the terrain of semiarid land using North-South slopes to make the land cultivable. Phase I will address the agrophysics[1] and the shape of the sloping terrain and is intended as a starting point to attract a relatively small amount of funding that will be easier to obtain than for more advanced stages.

The following topics are covered:

- Introduction and description of the concept
- Slope shapes and dimensions
- Evapotranspiration (ET) estimated by the Penman Equation and its variables and sub-variables
- Mathematical sensitivity analysis of the Penman Equation to evaluate its variables and sub-variables

- Expected microclimate and agrometeorology on narrow sloping terrains
- A procedure for the calculation and measurement of ET on narrow sloping terrain
- Determination of the sloping angle of the altered terrain that will reduce ET to match latitude, climate and growing season
- Soil erosion and water runoff
- Construction of a slope platform for lab testing
- Survey of regions for potential implementation
- Budget, funding sources, timetables, technical support and division of labor.



Typical natural North-South slopes in semiarid areas. The North-facing slope is lush, moist and green; the South-facing slope is dry and unusable.

Public Work in San Angelo, Texas. Grass appears spontaneously on the North-facing slope two weeks after digging.

Figure 1: Vegetation patterns on natural northern slope

- Assessment of ecological and environmental impacts

- Public perceptions and economic impact
- International collaborators
- References.

<u>Introduction and description of the concept</u>

The North-South slopes concept seeks to imitate vegetation patterns on natural hilly terrain in semiarid dryland regions where on the northern slope (in the northern hemisphere) solar irradiation is reduced since the slopes are partially shaded and therefore evapotranspiration (ET) is reduced, allowing for vegetation growth (Fig. 1). This could happen in places where flat terrain is devoid of vegetation. Our program involves the creation of N-S slopes by earthmoving and cultivation on the northern slopes. Semiarid regions experience scarce rainfall and cultivation there relies on irrigation using water from surface reservoirs or underground aquifers. In many semiarid regions, irrigation water supplies have not been developed or are not available.

Our Phase I will explore and develop a test lab by a collaboration of few research groups from a few countries. Following phase I of the program, phase II research will develop full-scale pilots to address different climates in few of the collaborating countries. Funding for Phase I and Phase II will be sought from the governments of the collaborating countries. A multinational R&D program is expected to attract the interest of developing countries' governments and world organizations that are interested in promoting economic development for developing countries.

Figure 2: The concept of north south slopes

<u>Slopes' shape and dimension</u>

The northern and southern slopes' widths are divided in a ratio of 2 to 1 or 3 to 1 in order to maximize the cultivable northern slope area. The southern slope is steeper and therefore to prevent soil erosion it could be covered by a plastic sheet. The sloping angle of the northern slope will be determined by the "necessary" reduction of evapotranspiration required for different climates and crops intended for cultivation.

The amount of earth moved by the construction of the slopes is proportional to the cross-section area of the slopes, which is proportional in turn to the square of the dimensions of the slope. To minimize the amount of earth moved and its associated cost, narrow slopes are preferable. But from the agronomic point of view wider slopes are more practical. In our program we will determine the optimal dimensions to address these considerations.

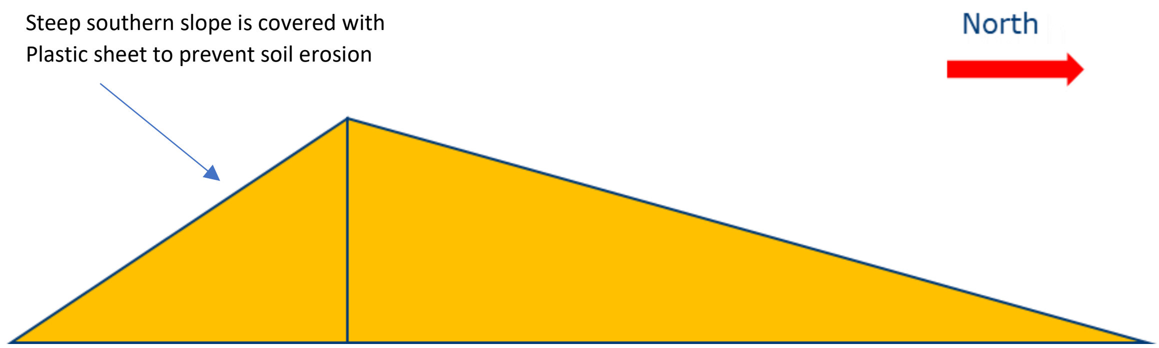


Figure 3: shape of the slopes – the width of the southern slope is smaller than the northern width to save land since the southern slope is not useable

Penman Equation and its variables and sub-variables

The reduction of solar energy on the slope is expected to reduce ET. A shallow sloping angle will not produce enough reduction in solar input and reduction of ET. On the other hand, an overly steep angle will excessively reduction of solar radiation and photosynthesis and also increase soil erosion and water runoff. An optimal altered ET will define the sloping angle for the "necessary" reduction of ET in comparison to that on flat terrain. The necessary ET will depend on local climate, growing seasons, and intended crops.

The Penman Equation (ref. 2, Eq. 3) for the calculation of reference ET uses weather variables as well as surface covered with low grass. More elaborate forms of the Penman Equation calculate an adjusted ET that uses a soil surface covered with taller grass and larger leaf coverage.

The climate variables for the Penman Equation are solar intensity, air pressure and temperature, wind speed and humidity and are measured by sensors placed 2 meters above the surface. The Equation's variables have their sub-variables and in most cases the Equation is simplified to address specific cases.

Our plan is to conduct a mathematical sensitivity analysis for specific cases on how ET is responding to a perturbation in the values of the weather variables or the sub-variables. For an approximation of ET some of these variables with less impact are omitted.

Expected microclimate and agrometeorology on narrow sloping terrains

The solar intensity over the slopes is dependent on the sloping angle, day of the year and hour of the day and can be calculated or measured by a pyranometer. Wind speed is altered over the slope and is dependent on the direction of the wind. Southern or northern wind perpendicular to the slope will have a different effect than wind parallel to the slopes. Air temperature and humidity over the slope are expected to be less altered by the slope than the wind while air pressure will not be affected by the slope.

A procedure for the calculation and measurement of ET on narrow sloping terrain

An ET sensor such as ETgage is placed 1 meter above the surface and provides an average ET over a field. Such an instrument is not adequate with narrow artificial slopes since the measurement will be affected by the ET from the southern slope. Therefore, for now we will use the Penman Equation for which the weather variables are solar intensity, wind speed, air temperature, pressure and humidity which are measured 2 meters above the ground.

But the flow and weather variables over the slopes at 2 meters are not representative of these variables close to the ground and near the plants since

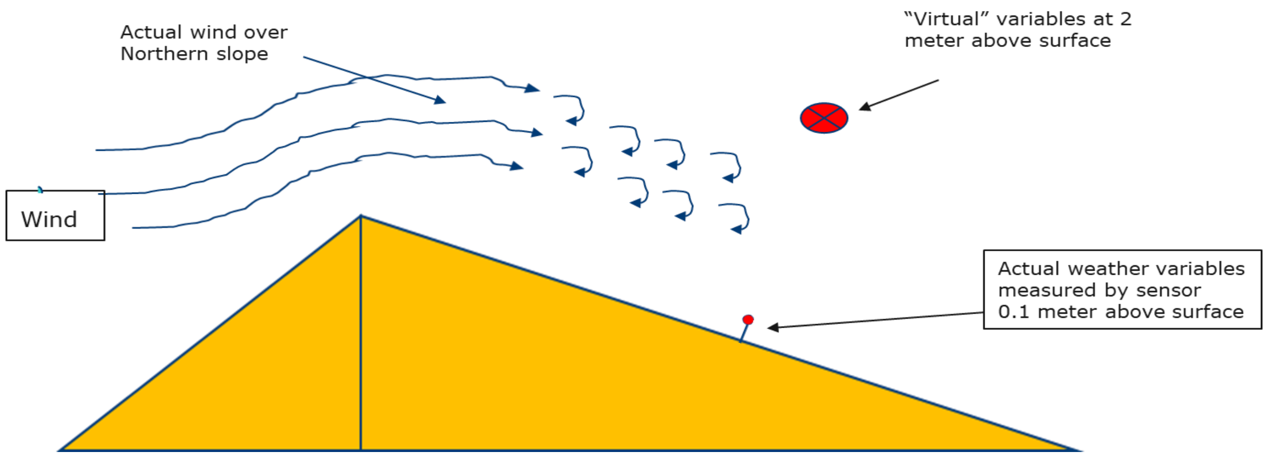


Figure 4: Schematic of the irregular flow over the northern slope and a weather sensor placed close to the surface. "Virtual" variables could be calculated at 2 meters as required by Penman Equation using logarithmic profiles of the boundary layers. The virtual values are not equal to the real variable values.

the boundary layer(s) over the slopes is highly irregular. We need therefore to develop a new methodology for which the weather variables will be measured close to the surface (~0.1-0.15 meter) and be extrapolated to provide these variables at 2 meters and then be plugged into the Penman Equation. The boundary layers for temperature, wind speed and humidity each have their own gradient profile over the slope. Therefore, one topic of our R&D will address the fluid mechanics and mass transfer for these variables and use a logarithmic profile of the boundary layer. The "virtual" values of these variables at 2 meters will be different from the real values 2 meters above the surface since these real variables are altered by the irregular air flow caused by the slopes.

<u>Determination of the necessary reduction of ET that will in turn determine the sloping angle of the altered terrain</u>

Any reduction of ET will decrease the difference between local precipitation and ET and the irrigation water requirement. The ideal case is when the new altered ET is less or equal to local precipitation. The altered new ET will determine the required sloping angle.

Soil erosion and water runoff

One concern is that the sloping terrain's soil will erode, requiring frequent correction and earthmoving. The steeper southern slope, which is more susceptible to erosion, could be covered by a plastic sheet. As for the northern slope, we can learn from how hillsides are stabilized for crops such as grapes and winter wheat.

The topsoil on the southern slope below the plastic sheet could be scrubbed and placed on the northern slope. Also, if soil is eroded on the northern slope it is not necessarily lost; it will accumulate in the areas between the slopes and if necessary could be spread on the slope every few years. Runoff water over the southern slope which is covered by plastic sheets can be collected and be used on the northern slope.

Mathematical models of soil erosion and water runoff are difficult to do with acceptable accuracy, so these topics could be studied on vegetation grown on natural slopes.

There were numerous investigations on cultivation and evapotranspiration on hilly natural slopes[4,5,6]. In none it has been suggested to alter or construct artificial slopes. Ours is a new focus – designing and constructing slopes' angle for a desired ET.

So far there was only one small pilot[7] for north-south slopes developed and tested in Israel in 1997 showing promising results. Evapotranspiration was not calculated nor designed and the sloping angle was chosen arbitrarily. The Israeli pilot was abandoned in 1998.

Figure 5: Hill-side vineyards and wheat cultivation

Construction of a slope platform for lab testing

In parallel to an earthmoving pilot on a few we propose to construct slopes using a frame covered by plywood boards. This way it will be easy to adjust the sloping angles frequently for testing. Such a structure can be portable and placed at different sites if necessary. The plywood will be covered by a thin layer of soil on which turfgrass sod will be spread for the low grass necessary for the determination of ET by the Penman Equation.

To measure potential evapotranspiration (PET) a Lysimeter could be used where a sample of soil and overlying vegetation on which measurements are made are representative in terms of soil water content and vegetation[3]. This involves the

Figure 6: A frame, plywood boards, topsoil layer and instant turfgrass carpets for the testing slopes. The frame sloping angle can be changed by lifting or lowering its edge

insertion of soil column in the ground which is isolated from the surrounding ground, and measuring continuously the column weight while a known amount of water irrigates the column. This is cumbersome and time consuming but doing so on a sloping platform is easier. A known amount of water could be provided by drip irrigation on the Lysimeter embedded in the wooden slope. The entire platform could be lifted or lowered to change and provide the necessary sloping angle.

Survey of regions for potential implementation

Climate and rainfall maps of regions in the US Southwest, Southern Europe, Middle East and India and overlapping maps of geochemistry and soil type will provide the information on possible sites for implementation. In addition, information is required for ecological assessment and jurisdiction and ownership of the land.

Timetables, technical support and division of labor for R&D

Budgets will be prepared by the collaborating parties for each R&D in their country. The collaboration will avoid duplication of efforts and will provide coordination for the program. Phase I is expected to take about 8 months.

Phase I 8 months	Research, lab construction and testing, survey, economics, proposals for Phase II
Phase II 18 months	Construction of full-scale pilot, agronomics and crops testing
Phase III	Implementation

Each group will address areas within their expertise such as geochemistry and soils sciences, hydrology and hydroclimatology, sensor development and remote sensing, ET measurement, ecological and environmental impacts as well as many other topics.

<u>Assessment of ecological and environmental impacts</u>

Environmental assessment and CO2 footprint will be performed. It will consider a carbon footprint due to, for example cultivation of cereal grains. For example, cultivation on new semiarid arable land created by the concept which creates carbon footprint will substitute for import of cereal grain from countries or regions where footprint is also being caused. Other carbon footprint considerations are covered in previous report.

Danger to wildlife will be assessed and passage for desert animals will be created each few slopes to allow easy passage. An assessment of the impact on biotics will also be done by the agronomists and soil scientists taking part in our program.

Public perceptions and economic impact

It is more than likely that environmental groups will object to the implementation of the N-S slopes and will attempt to produce negative publicity. But environmental policy decisions should be left for policy makers in the specific countries where implementation will take place.

15% of world surface area is semi-arid. The N-S slopes have the potential to produce jobs, to promote economic development and to provide food security for developing countries. In some cases, agribusiness corporations are likely to invest, buy land, upgrade and cultivate it for export.

collaborators

University of Perugia, Italy

Indian Council of Agricultural Research (ICAR), India

Universidade Federal de Campina Grande, Brazil

Utrecht University, The Netherlands

Universitat Politècnica de València, Spain

Oregon State University

Denmark Technical University

All are interested in joining an international collaboration that is expected to be funded by their respective government

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