Semiarid Terrain Alteration for Conversion into Arable Land - High-level Cost/Benefits Analysis

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Introduction

This writeup discusses some of the variables necessary for a cost/benefit analysis of the proposed north-south (N-S) slope program. Detailed analysis for specific sites, geographic locations and cultivation of specific crops cannot be performed at this stage and will be assigned to agricultural economists later.

Two main modes of agriculture exist: one is intensive, and the second is extensive.

Intensive cultivation is done on relatively small plots using large amounts of labor, fertilizer and water resources per unit area. Intensive cultivation is used mainly for fresh crops for local consumption, and its productivity per unit area is high.

Extensive cultivation uses large land areas but fewer resources per unit area and depends mainly on rainfall. Extensive agriculture provides most of the world output of human food and animal feed.

ReSlope Global's agenda is to apply terrain alteration for extensive agriculture on large semiarid land areas to produce mainly commodity crops. Of course, the slopes can also be used for intensive agriculture with a smaller overall economic impact.

The concept is geared to the conversion of unutilized dry land, which at the present time has no value. The premise is to retain rainfall through reducing evaporation from the soil and transpiration through plants (the combined term is "evapotranspiration," ET).

Two main variables influence the cost/benefit analysis. The first is the cost of earthmoving to create the slopes and shape them every few years; the second one is the real cost of local water (in contrast to that of subsidized water).

For this analysis, we assume that each earthmoving project has an economy of scale and will address hundreds or even thousands of sq. kilometers. For the sake of this analysis, let's assume a project of 100 sq. kilometers.

Earthmoving cost

The cost of earthmoving for the N-S slopes cannot be compared to that of earthmoving done on relatively small areas, such as for the foundations of buildings and road construction. In these operations, earth is dug by bulldozers and excavators and is transported certain distances by trucks.

In contrast, the terrain alteration for ReSlope Global requires no actual transporting of earth. The average level of the terrain remains the same as before the operation. The alteration requires relatively shallow digging and shoveling and landscape alteration without transporting earth.

Such operations could use graders (such as are used for road leveling or snow plowing, (see YouTube video). Because the vehicles do not need to turn frequently, stop or drive in reverse, they can cruise relatively fast in straight lines, making terrain alteration rapid and inexpensive.

Prior to terrain alteration, the site will require extensive surveys of soil type, geomorphology, climate and rainfall patterns. The Appendix provides detailed spreadsheet calculations for earthmoving construction and maintenance of a 100-sq.-kilometer project.

A summary is the following: 1/3 of the area is sacrificed for the unutilized southern slopes and for roads, so the obtained cultivable arable area is 66 sq. kilometer. The initial operation for N-S construction is scarifying, which tears the

Fig. 1: Earthmoving by graders for slope construction

top soil with a grader equipped with scarifying blades (see Appendix). The cost depends on the number of hours of the grader operation, which in turn depends on the width of the grader's blade and the speed of the grader. The fundamental equation[A1] for a Caterpillar 24M is:

$$\text{Production (sy/hr)} = \frac{5280 \times S \times W \times E}{9} \times \frac{1}{N}$$

where sy/hr. = square yard per hour, 5,280 = number of feet per mile, S = grader motion speed MPH, W = blade width (24 ft), and E = efficiency factor or 0.9.

For scarifying the grader's speed is low, 3 MPH. For shaping, the speed is 6 MPH. The blade width is 24 feet. The number of passes for initial construction is 2 for scarifying and 2 for shaping. We also assume 2 shaping passes each 5 years to correct for soil erosion. For the total project of 20 years, 3 additional shaping operations are required. Detailed calculations of cost are in the Appendix.

Accordingly, the cost of construction and shaping for a 20-year life-time project is $193.00/acre or $476.00/hectare.

For comparison the cost of land rental in the U.S. Southwest is $130/acre/year. In Italy the cost is $110 per acre or $247 per hectare. In other countries, however, the cost of rental land might differ; in some there may exist no land rental market at all.

Cost of water

The economics of water is complicated since it depends on the level of subsidies, the availability of underground and surface water and the energy and capital cost of pumping and piping water to the fields. Using our concept, however, retained rain falls exactly where the water is needed without pumping and piping.

The real cost of water is the subject of ongoing debate among economists. It is entirely possible that instead of the cost we should use the value of water, which is difficult to assess; thus, we will use cost of water for analysis.

Before assigning numbers, let's quantify the amount of water saved by rainfall retention. Assume for the sake of analysis that the site is the Dallas region, Texas, where the annual rainfall is 34 inch or 860 mm, but the area is still semiarid due to intense solar radiation and evapotranspiration.

Barley, oats and wheat each require 450-650 mm, and beans require 300-500 mm. This would mean that even a fraction of the rainfall is enough to replace the expenditure of (say) 600-mm water requirements. One acre = 4,000 sq. meters. This annual amount of water is equivalent to 2,400 cubic meters per acre which is 5,900 cubic meter per hectare.

The subsidized cost of farming water in California, for example, is ~ $100 per acre-foot while 1 acre-foot =1,200 cubic meters. This means that the cost of farming water is ~$0.05 per cubic meter. The worldwide cost of water is in the range of $0.02-0.10 per cubic meter (Bierkens et al., 2019).

Case in central Italy: We consider an agricultural district of central Italy (the Upper Tiber valley, Umbria region) with an area of about 77 sq. km, where a large part (about 70%) of the crops (mainly tobacco, maize, cereals, vineyards and olive groves) are irrigated (Dari et al., 2022). The annual mean rainfall is about 800 mm.

One of the most water-demanding crops in the area requires ~ 3200 m3/ha, i.e., 320 mm. The experimental evaluation of the actual ET is not straightforward. We can assume, on the basis of satellite estimates (MODIS), a mean annual value of ET and PET (potential ET) of ~ 500 mm and 1400 mm, respectively. Hence, it would seem that the annual rainfall could cover the water required, but the temporal distribution of rainfall, together with the high ET rates and the economic implications of the production of tobacco, necessitate irrigation practices. In fact, as shown in Figure 3, rainfall precipitation is lower during the summer months, i.e., from June to August, when crops require more water. Hence, the ET reduction induced by N-S slopes could also save irrigation water amounts over intensively cultivated areas. In Italy the cost of the water for agricultural purposes ranges between 0.02 and 0.05 €/m3, which is also $0.05/m3.

Therefore, in Italy, the reduction of ET might be enough to replace a portion, but not all, of the water for the required irrigation. Therefore, a farmer in Italy should decide if the reduction of ET is worth the reduction of arable land due to the need to sacrifice 33% of the arable land required for southern slopes.

This observation is correct in general even if we consider an average annual rainfall of 800 mm because of the seasonal distribution of the rainfall amounts. In any case, a reduction of ET in the summer surely would reduce the demand for irrigation. The costs-benefits analysis must obviously be done and depends on the expected percentage of reduced ET.

Coming back to Texas, the sloping terrain saves 2,400 cubic meters per year and per acre, so the additional water cost avoidance is 2,400*0.05=$120 per year per acre, which is comparable to the annual cost of land rental in Texas.

Even in California and Italy, for example, where existing semiarid arable cultivable land uses irrigation water, this concept makes sense even if it does not produce additional arable land. A farmer in California should decide whether to sacrifice

33% of her land for the southern slopes in order to avoid water costs via rainfall retention on the northern slopes.

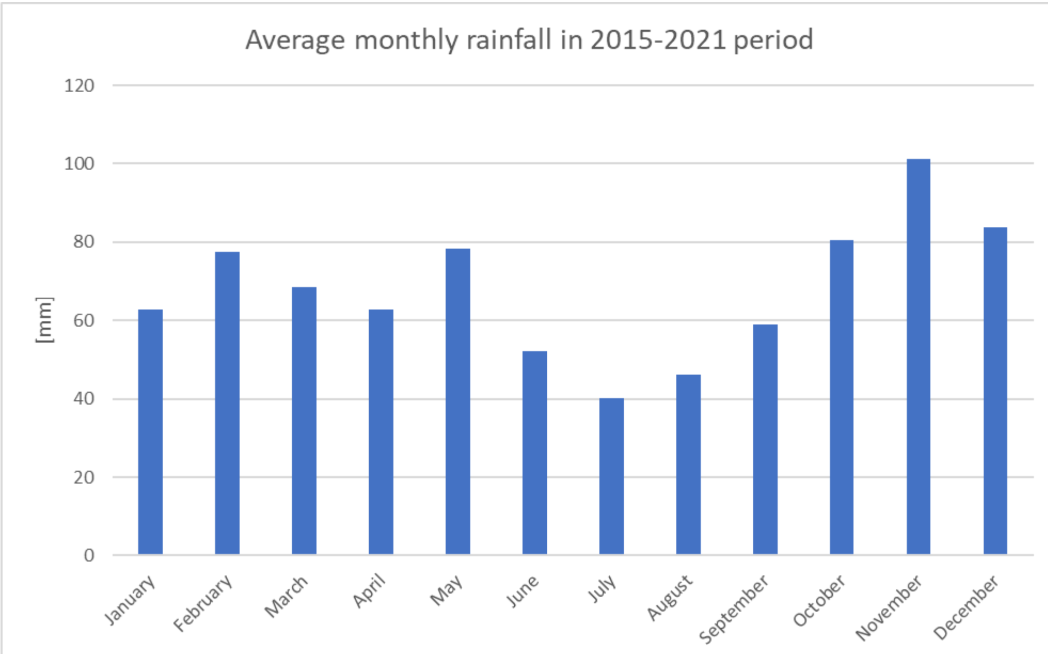

Figure 2: Average monthly rainfall over the Upper Tiber in 2015-2021. The mean value for the June-August trimester is ~140 mm.

Due to climate change, dire predictions exist for the availability of farming water in semiarid countries in the future, and it is more than likely that subsidies for water will be curtailed. This curtailment would mean that the water cost avoidance by the slopes will be even greater, providing further economic viability for the concept.

Detailed Economic Analysis

A thorough economic analysis for a specific project will include the net benefits/costs (NB)i of the investment for each year and calculating the net present value (NPV) over the project's duration. Once the initial capital cost of construction is known, depreciation will provide the annual cost of construction. For each year, a yield and a price are estimated as well as maintenance, labor, preparation, sowing, weeding and harvesting costs.

Assume that the project duration is 20 years. The calculation for the NPV of the investment follows:

NPV = sum(i=1,20) {NB_year_i/(1 + r)^i }, with r the discount rate.

Comment 1: Many developing countries import their food, which in turn causes food insecurity due to volatile food prices. Therefore, there are additional intangible favorable premium considerations for the slopes to substitute for food imports and ease food insecurity.

Comment 2: Semiarid land in many cases does not contain many organics. Therefore, it could become a carbon sink. Later, we will develop new technologies for carbon capturing by biochar and rock dust that will be used to add organics to the semiarid soil. This development will potentially provide carbon credit revenues.

Comment 3: This analysis shows four key benefits of the enterprise:

a. Formation of arable land;
b. Avoidance of water costs;
c. Food security; and
d. Carbon sequestration by the combination of using dust rock and biochar production systems, which could provide credit revenue.

The "real" cost of water is expected to increase drastically in the future. Therefore, the economics of the concept should become even more promising.

This writeup is a methodology and crude precursor for a detailed analysis that will be conducted by earthmoving experts, hydrologists and water economists assigned by ReSlope Global to make such analysis acceptable and demonstrate the economic viability of the enterprise.

References

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Veninga, Yoshihide Wada, Water Resources Research, Volume 55, Issue 5, pp. 4266-4287, 18 April 2019, https://doi.org/10.1029/2018WR023086.

2. Dari, J., Brocca, L., Quintana-Seguí, P., Casadei, S., Escorihuela, M.J., Stefan, V., Morbidelli, R., 2022. Double-scale analysis on the detectability of irrigation signals from remote sensing soil moisture over an area with complex topography in central Italy. Adv. Water Res., in press, 104130. https://doi.org/10.1016/j.advwatres.2022.104130.

Appendix

Construction Cost of North-South Slopes

We assume that unutilized semiarid land will be provided for free by government authorities for upgrading it into cultivable arable land using N-S slopes. It is expected, however, that in the future a market for unutilized semiarid land will be developed, so the land may not be provided for free then.

For an analysis, we assume a project on 100 sq. kilometers of semiarid land to convert into arable land by the construction of N-S slopes. Assuming that 33% of the constructed area is not useable, e.g., for the southern slopes and access roads, the calculations hereby are for 66 sq. kilometers.

The earthmoving construction is done by a Caterpillar 24M grader.

The governing equation1A for the earthmoving productivity of a grader in terms of area per hour is given by:

$$\text{Production (sy/hr)} = \frac{5280 \times S \times W \times E}{9} \times \frac{1}{N}$$

where sy/hr. =sq. yard per hour, 5,280 = number of feet per mile, S = grader motion speed MPH, W = blade width (24 ft), E = efficiency factor (0.9) and N = number of passes.

We assume 2 scarifying passes at S=3MPH for the initial construction of the slopes, and 2 passes for shaping and finishing at speed S=6 MPH.

Figure 3: Caterpillar 24M Grader scarifiers

Spreadsheet calculations for construction cost for 20-year project

Plugging into the grader productivity equation:

Scarifying speed S =	3 MPH
W-Blade width=	24 feet
E(Efficiency)=	0.9
N (passes)=	2
Hourly Cost/grader	$200.00
Grader hourly Cost per driver=	$40.00

Productivity(sy/hr)=	2,672	
ft/mile =	5,280	
sy/sqkm=	1.19E+06	
Productivity (sq. km) 1 grader=	0.010648739	
Total Area (sq.km)=	66.00	
Time (hrs)=	6,197.9	
Time (8-hr-days)	774.74 days	

Shaping S=6 MPH N=2 Passes

Because the speed is 6 MPH twice the speed for scarifying, the number of hours is for shaping is half of that for scarifying

Time (shaping) =	3098.9 hours	
Total hours for scarifying and shaping	9296.9 hours	
Total Grader hrs/month (8*28)=	224 hrs	1 month = 28 days
Cost of grader and driver/hr	$240.00	
Cost of total graders for Initial cost for shaping & Scarifying=	$2,231,250.00	
Per acre	$136.00	per 5 years

Cost of geo borehole survey	
1 borehole per 5 acres	$50.00
Total cost of geo boreholes	$815,100.00
Planning	$100,000.00
Total initial cost scarifying + shaping +	
geo Survey + planning	$915,100.00

We assume that every 5 years, the terrain requires a shaping operation to correct for soil erosion, so for 20 years project lifetime, 3 additional shaping are required (years 6, 11, and 16):

Cost of 3 shaping	$2,231,250.00
Total cost of 20 years project=	$3,146,350.00
Total cost per acre for 20 years	$193.00
Total cost per hectare for 20 years	$477.00

Reference:

1A: How to Measure Motor Grader Productivity, Caterpillar, (Click).