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Soil Erosion by Sustainable Phytoremediation Process Using Solar Irrigation

Balajiwaghmare[1], Madan Suryawanshi[2]

[1]Department of Geography, Dr. Babasaheb Marathwada University, Aurangabad [MS], India.

[2]Department of Geography, Dr. Babasaheb Marathwada University, Aurangabad [MS], India.

ABSTRACT: *Soil and land degradation is considered for slope land such as riverbank or stream bank and lands of high forced water runoff and rainfall causes severe soil erosion is the concern of this work. The major cause of runaway unprotected soil particles due to the natural reasons, thus making uneven soil plain surface scan be remedied by tree plantation or vegetation. A precision mirror-amplifier is designed for primarily sensing soil moisture and pH level to provide eventual environmental conditions needed for irrigation and fertilization for plants to grow healthy, which in turn reduces the soil erosion. Another special sensor designed and employed here that can monitor the degradation due to erosion and the system can determine the soil's critical limits. To design the system in an IC form, VLSI design MAGIC CAD tool is used to complete. Results from PSPICE has confirmed the proper performance of the IC and proved to be very applicable in the environment controlling systems. In this paper, design methods and results are presented for a sustainable cultivation technology to prevent soil erosion at slope land.*

Index Terms: *Soil Moisture; Irrigation; pH Level; Slope Land; Mirror-Amplifier; VLSI.*

I. INTRODUCTION

Land degradation is typically a more significant problem in areas with fragile ecosystems (deserts, semi-arid, volcanic islands, rainforests, etc.) and in places with heavy population loads where people are forced to over-use the same land with no alternatives. Degraded lands are also associated with areas where the land is the main resource for everything: human food, animal food, building materials, fuel, income generation, etc. These pressures create constant withdrawals that, if not reversed, lead to exhaustion of the land resource. Land degradation can be defined as reduction or loss of the biological or economic productivity of soil [1-3]. Among the several environmental damages caused by land degradation like (i) deforestation, (ii) erosion, (iii) loss of topsoil, (iv) siltation of streams and rivers, (v) reduced water infiltration, (vi) gradual drop in water table; this work is more concerned about erosion caused by wind and/or water. Figure 1 represents an impact caused by soil erosion.

a) Soil Erosion, Causes and Impacts

Erosion is the removal of soil particles from a site due to the forces of water, wind, and ice. Over time, these forces will slowly wear away or disintegrate the soil. Basically, erosion can be classified into two major types: (i) geological erosion, and (ii) man-made erosion. Geological erosion, which includes soil-forming as well as soil-removing, has contributed to the formation of soils and their distribution on the surface of the earth.

Flowing water and wind is the most common causes of erosion, and it may occur in several ways. Erosion of streams in agricultural areas normally occurs as a result of one of three factors: (i) change in stream flow, (ii) water flowing over or through the streambank, and (iii) the discharge of concentrated runoff from other sources. As flow depths and velocities increase, the force of the water flowing against the streambank removes soil particles from the banks, and in many cases erosion causes banks to slump and fall into the flowing water. In extreme situations where high flows persist over long periods, banks may erode several feet annually. Rain falling on streambanks or runoff from adjacent fields that enters a stream by flowing over the streambanks can also erode soil from streambanks, particularly if banks are inadequately protected. Finally, water discharged into a stream from tributary drainage systems (such as waterways or tile lines) can also erode streambanks, particularly if the water is discharged in an area where the bank is unstable and highly erodible [4]. Figure 1 and 3 are also representing the factors that influence the erosion [6].So in a brief what contributes to erosion can be listed as: (i) removing vegetation, (ii) removing topsoil and organic matter, (iii) shaping the lay of the land, (iv) exposing subsoil to precipitation, (v) failure to cover bare soil areas, (vi) allowing gullies to form and grow larger, (vii) removing vegetation along stream banks [6].

Figure 1. Heavy rainfall, steep slopes, removal of most existing vegetation, and erodible soils result in higher soil losses from erosion.

As the overall effects of erosion are felt on farm by the loss of soil productivity as well as off farm when soil sediments enter the water system causing siltation and eventual flooding of lowlands. In term of on farm effects, the relationship between soil erosion and agricultural productivity relate to the altering of soils properties. Erosion can decrease rooting depth, soil fertility, organic matter in the soil and plant-available water reserves [7]. Thus, the exposed soil remaining will be less productive in a physical sense. These effects may be cumulative and not observed for a long period of time. Erosion may also affect yields by influencing not only the soil's properties but also the micro-climate, as well as the interaction between these two [7]. In contrast to natural erosion which happens slowly, human-induced erosion can happen fast with large amounts of soil being removed. If this happens, it can be a serious threat to agricultural production and the environment [8].

b) Soil Erosion, Causes and Impacts

Riverbank or stream bank erosion protection can be done in several ways: (i) vegetation, (ii) windrows and trenches, (iii) sacks and blocks, (iv) gabions and mattresses, (v) articulated concrete mattresses, (vi) soil-cement, (vii) retaining walls. Besides that many other ways are possible to protect erosion. Among these ways, this work is concerned about vegetation, because it is the least expensive of riverbank protection measures, improves habitat, and aesthetically pleasing.

The vegetation process involves the deliberate planting of trees, shrubs, grasses etc., or retention of areas of natural vegetation (e.g. reforestation, contour hedgerows, natural vegetative strips) which: involve the use of perennial grasses/pasture legumes, shrubs or trees; are of long duration; often lead to a change in slope profile; are often zoned on the contour or at right angles to wind direction; are often spaced according to slope [8]. Figure 2 represents a typical vegetation process on slope land to protect from soil erosion process.

Figure 2. Slope land vegetation to protect soil erosion.

This work is more interested in vegetation process with a plant, locally known as Money Plant (in Figure 3). Scientific name of money plant is Epipremnumaureum which is a species of flowering plant in the family Araceae. Its native range extends from Northern Australia through Malaysia and Indochina into China, Japan and India. This is a root critter plant and often used in decorative displays in shopping centres, offices, and other public locations largely because it requires little care to grow; and this is the main reason of choosing it because it takes little care but with proper care it can grow vastly on long slope land to protect erosion.

Figure 3. Money Plants (Epipremnumaureum), an invasive root critter plant and also they grow on ground soil has been proven for excellent protection against soil erosion.

II. METHODS, APPLICATIONS, DESIGN AND MATERIALS

Keeping the soil covered with plant residues is the key to increasing soil organic matter and ultimately restoring degraded soils to the point that they can sustain crop production [1-3].

a) Erosion Control by Sustainable Irrigation

There is no doubt that plants can help slow down erosion. However, the soil on a steep slope is often missing nutrients for plants to grow. Water is also an issue on steep slopes because it moves downhill very quickly and does not soak into the soil. This makes it harder for plants to grow there. Keeping this in concern many technologies have been innovated to protect soil from erosion, and most of the technologies are pointed to the following 3 (three) goals. (i) Keeping the soil covered: bare soil is easily eroded by rainfall, especially on steeply sloped land. Mulching and the rotational/sequential planting of cover crops reduce soil erosion. Keeping the soil covered also shields it from harsh sunlight, moderating temperatures and thereby allowing soil organisms to thrive. (ii) Maximizing rain water efficiency/infiltration: rainwater harvesting strategies increase the percentage of rain water that percolates down into the soil, minimizing the amount of water lost to surface runoff. There are many techniques used separately or in combination to get this goal. Some of them include terracing, planting perennials along contours, and micro-catchments. (iii) Building soil and water conservation structures: these are physical barriers that prevent soil erosion on sloping land, protecting the soil resources of a farm or cropland. They can also be designed to capture water or increase infiltration, thereby lessening the negative impact of water on soil as well as increasing the availability of water for agricultural or other uses. While structures may have significant up-front cost associated with them, they can have immediate positive impact. They can be useful in stabilizing a severely damaged area, allowing subsequent erosion control strategies involving vegetation to succeed [1-3]. Figure 4 depits a slope land vegetation process using Live Staking/Brush Mattress method [9].

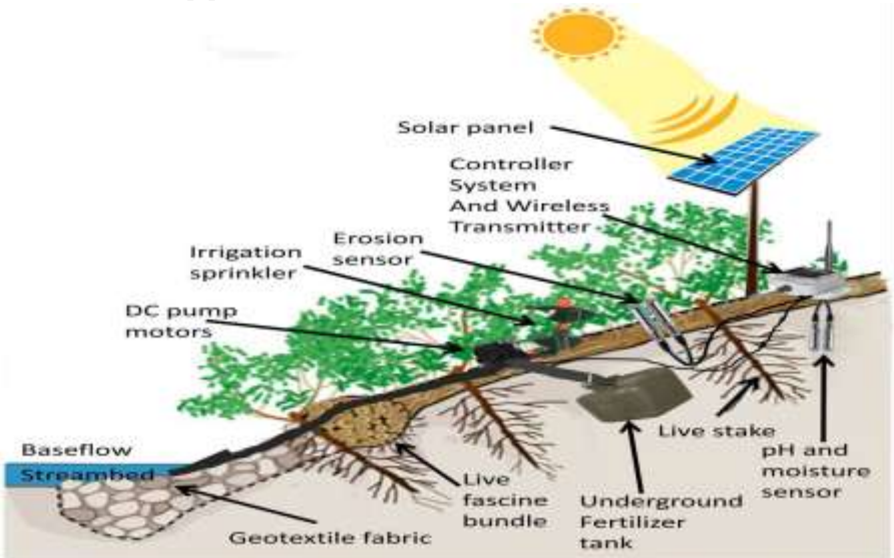

Figure 4. Illustration of an advanced system approach to slope land vegetation for preventing serious soil erosion.

b) VLSI Design of the IC

To have maintenance-free sustainable plants for many years, especially growing on the sloped land requires electronics with sensors that can perform complex decision making Logical Processes(mixed-signals) accurately. The system must maintain the programmed outcome, so plants on the field can stay healthy every season. This also requires carefully selecting the type of plants. For farming vegetation's, it requires extra attention and reprogramming the system based on the type of plants grown, suitable for every season. An IC design is essential that implements the logical functions to determine the exact operations that can offer the sustainable health of plants and thus this phytoremediation process prevents erosion. To design the system IC, based on precision sensor mirror-amplifier circuit and other modules in VLSI, MAGIC 7.5 is used with the process configuration of 0.5μm (SCN3M_SUBM.30). The circuit layout of the mirror-amplifier (in Fig.10) on silicon bar has area of 101λX48λ or 30.3μmX15μm using lambda=0.3μm CMOS design techniques, which is connected to the pin of 3V power supply. Lengths of all MOS transistors are same that is 2λ. For the input stage the ratio of p-MOS to n-MOS widths is 6:3 and for the input stage the ratio of p-MOS to n-MOS widths is 12:6. Three of the amplifiers placed in the IC with logical circuit configuration can control four modular functions previously shown in figure 5.

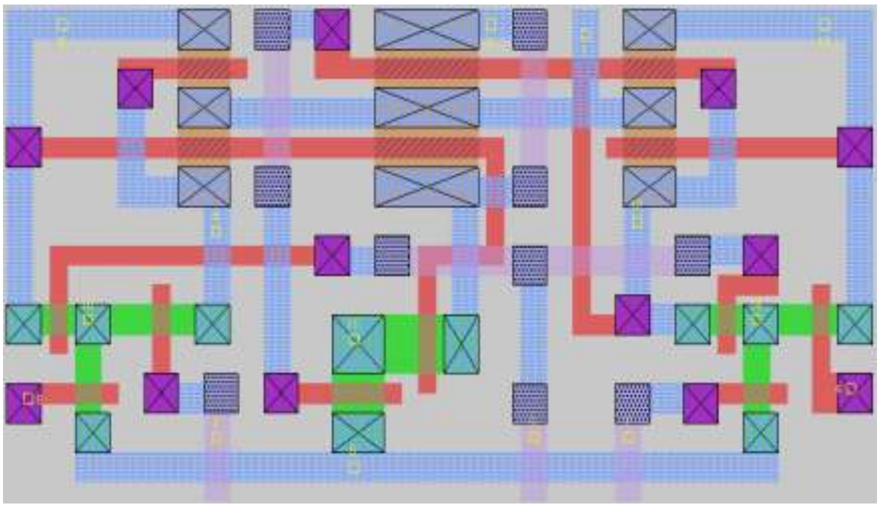

Figure 5. Physical layout for one of the mixed-signal mirror-amplifier in IC.

III. RESULTS AND DISCUSSION

Figure 6 represents the result of the designed precision sensor circuit using MAGIC extraction tool and PSPICE, which is done in two steps. In the 1st step, Output is taken with respect to node 4 (Vbias) with 0.4V DC (below threshold) supply at node 5 (Vsensor) and 0V to 1.5V clock pulse at node 3 (Clock). In this case output toggles and get steady at 1.4V giving a power dissipation of 1.66 mill watts. It is found that Hysteresis at threshold voltage level causes dynamic power loss [11]. This design has flexibility of voltages to bias CMOS circuitry. So the pin configuration is changed to get desired response. In the 2nd step, output is taken with respect to node 5 (Vsensor) with 1.4V DC supply at node 4 (Vbias) that is got in the 1st step. Clock pulse is still 0V to 1.5V. In this case output toggles and get steady at 0.18V. Power dissipation is found to be 4.39 Nano watts in this case. Thus the system is improved for our desired operation with Nano-power dissipation.

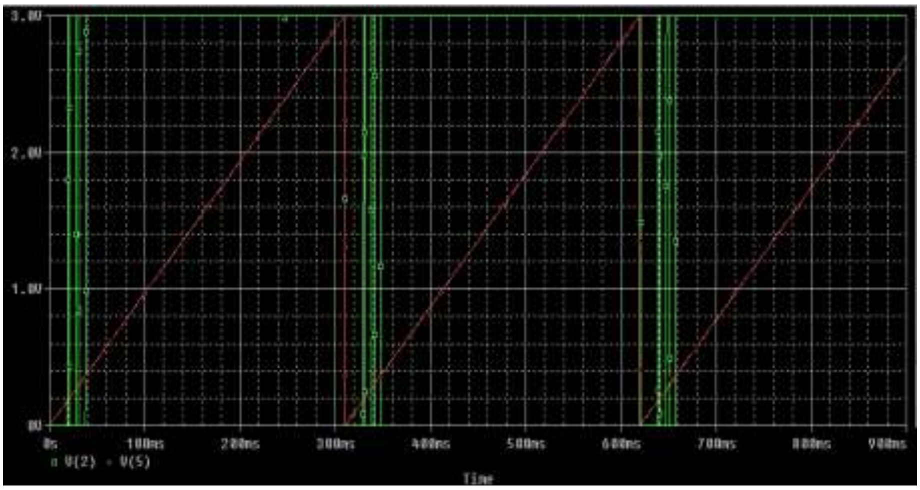

Figure 6. Plot of the PSPICE results of the VLSI sensor circuit in the IC

Now Vbias can be set depending on the moisture level conditions of the slope land. The Vsensor senses moisture levels accurately, all the time for the IC to activate water hoses to increase moisture level of the field as necessary. Similarly, Vbias can be set for sunlight conditions for each type of betel plants based on light conditions in a particular field. Sunlight shutters are controlled by sensor signal to Vsensor of the chip. As a result, the system applies power to electric motor to control shutter position. Thus the perfect sun lighting condition is created for the field throughout the year.

IV. CONCLUSION

The UNCCD estimates that over 250 million people are affected by land degradation, and about 1 billion people in over 100 countries are at risk. According to the WMO, 33% of the world's land surface is vulnerable to land degradation. Breaking that down further, they estimate that 46% of the land in Africa is vulnerable, with Sub-Saharan Africa being the most vulnerable; 25% of Asian lands are vulnerable. [1-3]. In addition, soil erosion is one of the major factors regarding this risk which can be significantly reduced by vegetation process with proper care by controlling the environmental conditions. Towards that a solar powered complete system is designed which is composed of an IC based on pre-designed mirror-amplifier with two separate control segments for different controlling parameters, depending on the necessity of different cases, including the precision irrigation modules and fertilizer modules for the vegetation process with Money Plant at slope land. The chip designed in CMOS 0.5μm fabrication process has the total layout area of 297μmX304.2μm. Using this IC with sensors, the controlling system can satisfy the controlling with a number of advantages including greater precision, more efficient use of water and fertilizer, and reduction in human errors. With the application of this research, farmers can maximize the vegetation process by growing healthy plants on the slope lands.This is a multi-level beneficial process where both farmers and duellers can eliminate the risks of soil erosion and landslides.

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