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Highlights

Atmospheric CO_2 Purification

Rangeland Suitability Evaluation

GIS Techniques in Dire District

Approach to Power Generation

Discovering Thoughts, Inventing Future

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The Atmospheric CO_2 Purification Method

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Abstract- Our approach incorporates the effective stepwise CO_2 purification in the free atmosphere by spraying of alkaline compounds together with acoustic acting inside the cloud via an aircraft. The alkalis cause significantly increases of the CO_2 solubility in further rainy droplets during their gravitational fall to provide the effective carbon transport from under-cloud atmosphere to the ground. The second step proposes an acoustic influence where droplets are triggered inside clouds by sound waves for coalescence. Special acoustic generators are considered, also optimal regimes for cloud droplets have been found at low frequencies with necessary acoustical power. The proposed alkaline method can compensate for annual carbon emission by its application at 0.4% – 0.1% at our planet surface.

Keywords: *atmosphere, co_2, precipitation enhancement, clouds, acoustics.*

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THEATMOSPHERICCO2PURIFICATIONMETHOD

Strictly as per the compliance and regulations of :

The Atmospheric CO_2 Purification Method

Svetlana Amirova [α] & Tamara Tulaikova [σ]

Abstract- Our approach incorporates the effective stepwise CO_2 purification in the free atmosphere by spraying of alkaline compounds together with acoustic acting inside the cloud via an aircraft. The alkalis cause significantly increases of the co_2 solubility in further rainy droplets during their gravitational fall to provide the effective carbon transport from under-cloud atmosphere to the ground. The second step proposes an acoustic influence where droplets are triggered inside clouds by sound waves for coalescence. Special acoustic generators are considered, also optimal regimes for cloud droplets have been found at low frequencies with necessary acoustical power. The proposed alkaline method can compensate for annual carbon emission by its application at 0.4% – 0.1% at our planet surface.

Keywords: atmosphere, co_2, precipitation enhancement, clouds, acoustics.

I. Introduction

The idea of weather modification by precipitation seeding was generated earlier by Vincent Schaefer and Irving Langmuir [1]. The most popular methods used today for precipitation enhancement are the sprinkling of hygroscopic particles or a special solutions for 'warm' clouds and the introduction of glaciogenic substances into 'cold' clouds from an airplane [2-6] and etc. According to IPCC Fifth Assessment Report the predicted climate trend indicates the global overheating [7] up to the end of century, and all known natural restore mechanisms have limited capacities in regards to the amount of incoming pollution and also they operate within specific time constants according to [8]. We recall that the sum of water vapor and carbon dioxide makes a 95% of the greenhouse gases in a modern atmosphere. Mentioned aspects we used to propose new method for atmosphere purification and further climate recovery.

Our approach incorporates the possibility of stepwise CO_2 purification in two simple stages to be conducted in areas of the free atmosphere. The first stage involves spraying of alkaline compounds, such as *KOH* and etc., inside the cloud via an airplane to increase the *pH* in cloud droplets. The alkaline reagents significantly increase the solubility of CO_2 in water, however rain droplets become saturated by atmospheric CO_2 during their gravitational fall. Due to the small CO_2 concentration in air the probability of collision in cloud between small water droplets and CO_2 molecules is low, so modified cloud droplets spend their alkali capacity later during rain. The rainy droplets provide effective transport of CO_2 from the under-cloud atmospheric volumes to the ground and further more to soil, ground water and plants.

In addition to it, the special acoustic devices can be utilized to accelerate the coalescence of water droplets in modified clouds as possible second stage of proposed method according to [9]. The acoustically influencing for mists and fogs was widely used early [10-13] then industrial aerosols were the central purpose for the acoustical seeding, and common practice show the efficiency up to 99%. The background is the facts that acoustics provides high mobility for droplets, because they become be involving into air vibrations inside sound waves with the best coalescence as a results. The speed of acoustic-based vibrations and coalescence should be effective for cloud droplets due to high speed of acoustic waves (C ~ 340 m/sec) in comparison with typical atmosphere winds 2 – 20 m/sec. Previous acoustical experiments were only carried out near the ground earlier, but it could be most effective to place the sound generator directly inside a cloud in the region with oversaturated water steam by using a modern airplanes or helicopter.

II. The Features of Proposed Method for CO_2 Purification

The purification effect strongly correlates with changes of *pH* level in cloud water. In natural precipitation with acid or neutral *pH* the concentrations of the dissociated ions are relatively small. On the other hand, the natural ocean of our planet stores great mass of CO_2 due to alkali properties of the ocean water where is $pH \approx 8.3$. There is an established method to describe the insoluble and dissociated portions of the weak acid that remains after attaining the equilibrium of saturation for water by CO_2 : $CO_2 + H_2O \Leftrightarrow H_2CO_3$, $H_2CO_3 \Leftrightarrow HCO_3^- + H^+$ and $HCO_3^- \Leftrightarrow CO_3^{2-} + H^+$. The equilibrium concentrations of dissolved and dissociated portions became $[H_2CO_3] = C_1 = 0.71$ mg/l; $[HCO_3^-] = C_2 = 3.3$ mg/l, also $[CO_3^{2-}] = C_3 = 10^{-3}$ mg/*l* then $pH = 7$, and given data were listed for a cloud with 3 mkg/m^3 of NH_3 [14-15]. Therefore, CO_2 solubility significantly grows at higher *pH* levels due to increase of H^+ concentration, and concentrations of ions $[HCO_3^-]$ and $[CO_3^{2-}]$ increase in 10 and 100 times accordingly by each unit of *pH*. The ratios of carbon in the first, second

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and third of the listed compounds are the following: D_1 = 0.1935; D_2 = 0.1967; and D_3 = 0.20. For given water volume U_w the carbon mass can be calculated as:

$$M_C^{Uw}(pH) \approx \left[\ 0.1935 \cdot C_1 + 0.1967 \cdot C_2(pH) + 0.2 \cdot C_3(pH)\ \right] \cdot U_w \quad (1)$$

For instance, a precipitation layer with a height of h_w = 1000 mm covers a unit surface of 1 m^2, so the corresponding mass of carbon is equivalent to $M(10) = N_S(10) \cdot 1000 \approx 850$ g at the pH = 10. Using this approach one can estimate the concentration of CO_2 that is removed from the atmosphere underneath the cloud by precipitation. Let's take the volume of purified air in the atmosphere U_a = 10^3 m^3 in precipitation, there h_a = 1 km is the altitude of the cloud calculated from the ground for a unit square surface 1 m^2. The reduced CO_2 concentration C_{a-} could be estimated by dissolving the carbon mass in alkaline precipitation water:

$$C_{a-} \approx \frac{0.1935 \cdot C_1 + 0.1967 \cdot C_2(pH) + 0.2 \cdot C_3(pH)}{0.2727} \cdot \frac{h_w}{h_a} \quad (2)$$

The molar mass of CO_2 is 44 g, so the share of carbon in it is D_4 = 12/44 = 0.2727. The vertical CO_2 distribution was considered here almost uniform [16] up 2-3 km, excluding increase in 100-200 meters near ground. For the special case of the complete atmospheric purification in the volume under cloud, we assume that the CO_2 concentration is $C_{a-} \approx$ 420 ppm. The pH level of the droplet should be increased up to pH=10.3 for complete purification if the cloud located at 1 km above the ground. In general, clouds can be located at various altitudes h_a. For instance in case of the altitude h_a = 6 km the cloud medium should become pH=10.8 to get complete purification in lower area. Let's analyze a chemical approach to introduce KOH into clouds in the form of additional liquid aerosol. There is the dissociation reaction of KOH in water:

$$KOH \rightarrow K^+ + OH^-$$
$$H^+ + OH^- \Leftrightarrow H_2O \ , \ K_w = \left[H^+\right] \cdot \left[OH^-\right] \quad (3)$$

We note that the values of water dissociation constant are taken at variable temperatures: K_w=10^{-14} at T = 20°C according to [17] or K_w = 10$^{-14.926}$ at T = 0°C in cloud. The required KOH mass can be obtained approximately from the relation $n_{KOH} = K_w / \left[H^+\right] = \left[OH^-\right]$ according to algorithm of (3). Taking the equality of molar concentrations for KOH and OH from relation (3) we obtain the molar concentration of alkali n_{KOH} = 10^{-4} mol/l then pH = 10, for example. The mass concentration value N_{KOH} = 56·10^{-4} g/l ≈5.6·10^{-6} g/cm^3 results from molar one by multiplication to the molar mass of KOH. Let's comment upon the data. Suppose in a cloud the liquid water content is W = 1 g/m^3, it means that air volume 1 m^3 contains the 1 cm^3 of water, and listed data of N_{KOH} corresponds required alkali mass to air volume 1 m^3 (5.6·10^{-9} kg/m^3) to get mentioned pH-level in cloud droplets after evaporation/condensation and restructuring. For example, let the cloud has a volume 1 km^3 and W = 1 g/m^3, hence the required mass of KOH to add into this cloud should be equal to 5.6·10^{-9}·10^9 ≈ 5.6 kg then pH = 10 approximately. Exact calculations for KOH mass were performed with account of condensation processes onto aerosol particles in real cloud [18]. The average KOH concentrations as a function of pH are N_{KOH} = 1.7·10^{-5} g/cm^3 then pH=10.5, and N_{KOH} = 3.5·10^{-5} g/cm^3 then pH=10.8 in comparison with N_{KOH} =5.6·10^{-6} g/cm^3 then pH=10.

We investigate a potential purification advantage of this method based or droplets assemble above the flat ocean surface. Firstly, due to small size of rain droplets the falling time exceeds the gas saturation time to provide perfect CO_2 absorption. The fall velocity $V_g(r)$ can be using the stationary speed of droplet gravitation sedimentation as follows: $V_g(r) \approx \sqrt{2rg\rho_w / \rho_a}$, where ρ_a and ρ_w are the densities for air and water respectively, r is a drop radius and g is the acceleration due to gravity. The falling time for droplet can be estimated as $t_h \approx h_a / V_g(r)$ with the initial cloud altitude of h_a = 1 km, these calculations show t_h =257 sec then r = 1 mm for example. On the other hand, we can estimate the saturation time t_{aw} for the falling droplets during the process of CO_2 solubility. The steady state concentration depends on the ratio of the air volume $U_r = 3\pi r^3/3$ for the drop and the area of its surface $S_r = 4\pi r^2$, and also depending on the gas exchange constant K_{aw} at the gas-water interface, the time of saturation is $t_{aw} \approx r/3K_{aw}$. The constant $K_{aw}(V)$ has been measured as a function of the velocity of air flow V over the water surface, according to [19-10]. We employed the following experimental measurements for constants of gas exchange at the gas-liquid interface: $K_{aw} \approx 4 \cdot 10^{-3}$ cm/s then V = 3 m/s; also $K_{aw} \approx 1.1 \cdot 10^{-2}$ cm/s if V = 7 m/s. Taking into account $K_{aw}(V)$ we obtain saturation time t_{aw} = 6 sec for droplet with a typical rain radius r = 1 mm. The largest radius in rain has been estimated as 3 mm due to drop disintegration, and at the beginning of the precipitation due to gravitational sedimentation the droplets have grown with radius $r \geq 100$ μm. For the largest droplet with radius r = 3 mm saturation time is t_{aw} = 11 sec and flying time t_h = 148 sec due to velocity $V_g \approx 7$ m/sec. As $t_{aw} << t_h$ there is enough time for gas saturation during droplet flight to the ground from the altitude $h \geq 1$ km.

The next method's advantage is great increases of the air/water interface in droplets assemble in comparison with flat surface of ocean. Further analysis bases on the Marshall-Palmer approximation for the droplets spectrum for rain as follows

$\varphi(r) = n \cdot b \cdot \exp(-br)$. This empirical formula includes the constant *b* (cm^{-1}), and the droplet number concentration *n* (cm^{-3}) that depends on the precipitation rate *I*, in millimeters per hour [21-22]. Different types of precipitations can be described by previous empirical equation for the parameters *b* and *n* using in, as follows: drizzle has $b = 57 \cdot I^{-0.21}$ with $n = 5 \cdot 10^{-3} \cdot I^{0.21}$; rains have $b = 41 \cdot I^{-0.21}$, $n = 2 \cdot 10^{-3} \cdot I^{0.21}$; and storms have $b = 30 \cdot I^{-0.21}$ with $n = 5 \cdot 10^{-4} \cdot I^{0.21}$. The radii interval for the complete rain spectrum was calculated over a wide interval r = 0.05 - 3 mm. The volume of received precipitation water $U_I = AIT\beta$ was calculated as a sum of all of the falling droplets, there the water layer is *I* on a ground surface A = 1 m^2 during $T = 1$ hour for all calculations as mentioned in the examples. Here rates for drizzle, rain or storm are I = 3; 10 or 30 mm/hour, , but the β coefficient was introduced in order to compare the features for the precipitation types, $\beta_1 = 1$, $\beta_2 = 0.3$ and $\beta_3 = 0.1$, so $I_1\beta_1 = I_2\beta_2 = I_3\beta_3$. Then the percentage of droplets with a radius r_i within the unit water volume can be described using normalized number of droplet $q_i(r_i) = \varphi_i(r_i)/\Sigma\varphi(r)$. The sub-volume of the unit volume $U_I(r_i)$ for these droplets with equal radii can be estimated as $q(r_m) \cdot U_I$, also the number of droplets in each sub-volume consist of $N_m = 3q(r_m)U_I/(4\pi r_m^3)$. The total sum for the entire droplet intervals in all volumes of sub-volumes $U_I(r_i)$ are described by the following sum:

$$N = \frac{3AIT\beta}{4\pi} \sum_r \frac{q(r)}{r^3} \qquad (4)$$

Calculations according to (4) provide the total number of falling droplets in mentioned water unit. For drizzle it is $N_d \approx 6.76 \cdot 10^{11}$, for rain $N_r \approx 4 \cdot 10^{11}$, and for storm $N_s \approx 2.45 \cdot 10^{11}$ for $AIT\beta = 3$ liters of water for drizzle, rain, or storm. These results prove that rain droplets could be interpreted as a porous medium with a large surface for gas/liquid interactions as compared to the ocean's plane surface. Then, each falling droplet runs at an air cylinder with a minimal volume length h and a ground area πr_m^2. The cylinder surface $S_m \approx h2\pi r_m$ means that air/water interface increases for rainwater and purified air contact. The total sum of this surface for all droplets in considered water unit is, as follows:

$$S \approx \sum_r N_{m,I} S_m = \frac{3AIT\beta h}{2} \sum_r \frac{q(r)}{r^2} \qquad (5)$$

provide the following numeric values: $S_d \approx 3 \cdot 10^8$ m^2 for drizzle, $S_r \approx 2 \cdot 10^8$ m^2 for rain, and $S_s \approx 10^8$ m^2 for storm. The corresponding calculations for expanded atmospheric air/water interface considering droplet set were done in precipitation volume $S_{hA} = 4 \cdot 10^3$ m^2 with altitude h_a = 1 km and ground surface A = 1 m^2 for precipitation time T = 1 hour. As a result, the formula (5) demonstrates the 10^5 times increase in air/water surfaces for purification possibilities as a result of rain. Due to their linear contribution in formulas for *N* and *S*, the values of *T*, *h*, *I*, and *A* can be multiplied by any numeral for real time, altitude, rain intensity or grand square. Due to the small CO_2 concentration in cloud media the probability of collision between water droplets and CO_2 molecules is low; but erosion of CO_2 as well as a significant decrease in its concentration occurs in the sub-cloud precipitation volume.

An extra advantage of proposed approach is very positive plant response to the precipitation resulted from proposed method. To emulate the process of CO_2 absorption in water droplets during an indoor experiment, the similar changes were made in alkaline solution during long-time diffusion according to formula $L_{lab} \approx (D \cdot t)^{1/2}$, diffusion coefficient is D =$\cdot 10^{-5}$ cm^2/sec, but L_{lab} there is a water layer depth. The *KOH* was dissolved in water and resulting mixture was kept indoors during several hours $t = L^2_{lab}/D$, as a result the solution has ions of $K+$; HCO_3^- ; CO_3^{2-}. The initial pH = 12 was kept in these experiments. After 9-hours of saturation time *t*, the plants in brown pot were given the resulting solution, but the same volume of pure water was added to control blue pot (left side) with the same plants, Fig.1(a-d). These two watering processes were repeated regularly every day during January 2014. The experimental plants are beetroots (10 grains), carrots (20 grains), and much number of parsley (2 Grams) in each of plant pots, see Fig.1(a,b,c).

a

b

c

d

Figure 1 : The indoor plants after 0 (a), 19 (b) and 30 (c) days correspondingly; (d) is the next plants after 19 days in the same soils with the same watering procedures. The plants in a right (brown) flower pot were watered by solution with ions CO_3^{2}; HCO_3^- ; K+.

The second experiment was done later with the same soil after deleting previous plants; the next portion ware planted, there are 20 grains of dill and 5 grains of cucumber for each plant pot. The same watering process was repeated regularly every day during February 2014, results are presented at Fig.1d. One can see a strong vegetation growth by enriched solution watering according to proposed method for all studied plants.

III. The Method Perspectives for Climate Recovery

In general the proposed method can be applied for the whole Earth on the global scale. The surface area of our planet is $A_E \approx 5{,}1 \cdot 10^8$ km^2 and the average annual layer of precipitation is $h_w \approx 1{,}000$ mm. Using equation (1) one can estimate the mass of removed atmospheric carbon (M_C^1) in 1 meter of precipitation water measured per surface 1 m^2 at $pH = 10 - 10.8$, for details see 1st and 2nd rows of Table. The carbon ratio in CO_2 is 0.2727, hence the amount of carbon oxide is $M_{C02}^1 = M_C^1/$ 0.2727 and its value listed at the 3th row of the Table. Note, the $M_{C02}^1 = 5.9\cdot\cdot10^{-4}$ then pH=5.6 for typical rain.

The calculated mass of formed carbon at the surface A_E of the whole planet is $M_C^A = M_C^1 \cdot A_E = 0.849 \cdot 5.1 \cdot 10^{14}$ $\approx 4.3 \cdot 10^{14}$ kg then $pH = 10$, as listed at the 4th row of the Table. The CO_2 value $M_{CO2}^A = M_{CO2}^1 \cdot A_E = 3.11 \cdot 5.1 \cdot 10^{14} \approx$ $1.6 \cdot 10^{15}$ kg listed at the 5th row of the Table. In 2010 the global CO_2 emission reached an amount of $3.06 \cdot 10^{13}$ kg. For further calculations let's assume the global annual emission of CO_2 as the value $AE = 3.2 \cdot 10^{13}$ kg, for example. To compensate an annual CO_2 emission from the ratio AE / M^A_{C02} we estimate the minimal area at the Earth's surface (A_p, %) to be used for proposed technology and the corresponding details are given at the 6th row of the Table. For our approach the proposed method could to be applied on 2% - 0.14% of planet surface to compensate the annual carbon emission. To sum up let's estimate the mass of alkali to add for desired modifications in clouds. The mass *KOH* (Q_{KOH}) can be estimated using previous data for n_{KOH} from (3). Considering the precipitation layer of 1 m/year for the planet surface *A* its necessary percent *(%A)* can be estimated from the Table. The added mass of alkali at $pH = 10$ level is calculated here:

$$Q_{KOH}^{10} = n_{KOH} \cdot 1 \cdot A \cdot (A_p) \approx 5.6 \cdot 10^{-3} \cdot 1 \cdot 5.1 \cdot 10^{14} \cdot 0.02 \approx 5.7 \cdot 10^{10} \text{ kg} = 57 \text{ mil.Tons} \quad (6)$$

Note that similar estimations are presented at the bottom row of the Table. In comparison with the fertilizers for soil the added mass of alkali is relatively small. A required modification of the clouds can be achieved with the help of aircraft by spraying alkaline aerosol particles on top of the clouds and also by lifting of alkaline gas from the ground [18].

Table 1 : The carbon mass ($M^A{}_C$) and CO_2 mass ($M^A{}_{CO2}$) for the Earth's surface $A_E = 5.1 \cdot 10^8$ km^2; the minimal required surface (A_p) and mass of KOH (Q) to compensate an annual carbon emission

1) pH-level	10	10.5	10.8
2) M_C^1 per 1m^3, kg	0.849	4.05	12.06
3) M_{CO2}^1 per 1m^3, kg	3.11	14.8	44.2
4) $M^A{}_C$, mil. Tons	$4.3\cdot\cdot10^5$	$2.1\cdot\cdot10^6$	$6.2\cdot\cdot10^6$
5) $M^A{}_{CO2}$, mil.Tons	$1.6\cdot\cdot10^6$	$7.7\cdot\cdot10^6$	$2.3\cdot\cdot10^7$
6) A_p , %	2%	0.42%	0.14%
7) Q_{KOH} ·, mil. Tons	57	38	25

IV. Acoustical Impact Inside Cloud for Droplet's Coalescence

The most interesting perspective for today is a joint utilization of two methods at the same time, which means that hygroscopic particles and acoustic influence would be directly applied inside one cloud area. Dynamics of different hygroscopic particles show that only first 15 ÷ 20 seconds demonstrate very fast changes in the main cloud characteristics as the supersaturation and spectrum dispersion. This is accompanied by an increase of the radii inside small drops from 0.01 ÷ 0.1 μm up to 1 ÷ 3 μm. So, after the first major variations of these parameters they increase with the same tendencies very slowly, so significant changes in spectrum of cloud and precipitation increase up to time 30 – 50 minutes [5]. It could be understood as initiation of water vapor condensation onto surface of hygroscopic particle from surrounding, but next stage will be the evaporation from the host cloud droplets with further condensation to new particle, such reorganization need much time. The idea is that drops could be triggered by sound waves in the form of vibrations to provide the coalescence to a drop size of more than 100 μm, and after this point gravity will predominate.

The propagation, absorption and attenuation of sound in clouds decrease with distance *(x)* in ideal air media, as follows:

$$P = P_0 \exp(-\alpha x),$$

$$\alpha = \frac{b \cdot \omega^2}{2\rho \cdot C_a^3},$$

$$b = \frac{4}{3}\eta + \frac{\gamma - 1}{C_p} \cdot a_T + \eta' \approx 2.5 \cdot \eta \qquad (7)$$

The absorption coefficient α of sound in the medium is expressed in m^{-1}. There ω is a sound circular frequency in air, η is the dynamic viscosity, the C_p heat capacity at constant pressure and the ratio of specific heat capacities is γ, the a_T is a thermal conductivity (m^{-1}). Theory predicts the absorption maximum in the range of few tens of Hz. Attenuation β may be expressed in sec^{-1}, then the value of α (m^{-1}) must be multiplied by the speed of sound. Measurements in the water mist then water liquid content is W = 2 g/m^3 for the more interesting frequency range for further consideration are: β = 3.5 dB/s for *f* = 58 Hz; β = 2.8 dB/s for *f* = 112 Hz; β = 3.6 dB/s for *f* = 150 Hz; β = 6.7 dB/s for *f* = 200 Hz [13]. Measurements and calculations indicate further sound attenuation is not high $\alpha \sim 10^{-3} \div 10^{-2}$ dB/m in dry air, then the sound frequency is *f* = 3 ÷ 10 *kHz*. As the humidity increases up to 12 ÷ 20 % , the attenuation increases up to 0.17 ÷ 0.56 *dB/m*. For higher frequencies the attenuation does not depend strongly on the humidity and give the values: $\alpha = 0.15 \div 0.05\ m^{-1}$ then *f* = 20 *kHz;* and etc. Using mentioned measured data we deduce that at low frequency (*f* = 50 - 200 Hz) the acoustical wave can propagate ~ 500 meters in typical clouds prior to decreasing in energy by a factor of 2. The *x* = 0.5 km is enough distance in cloud for initiation of the reorganization for precipitation to begin. In practice, the most effective glaciogenic particles run the distance of ~0.1 km in cloud from airplane prior to their evaporation or sublimation, such distance provides enough cloud reorganization for precipitation enhancement. The effects of the partial dissipation of irradiated sound waves during their propagation in a turbulence medium have been measured and considered in [23-24], for example. Clouds with plenty or prolonged rainfall are identified as *Ns, As, Cb* and *Cu*, they are more important for the active actions of precipitation enhancement. Autumn and spring clouds are mixed with water droplets, ice crystals and snowflakes. The authors of papers [25-26] studied the formation and shapes of cloud fractions using both experiments and theories, they gave convenient empirical formula that can be employed in order to determine the percentage of water vapor, liquid, and solid phases in real clouds created by the adiabatic process.

The purposes of further analyses is to calculate an amplitude, *L(r,ω)*, during the vibrations for typical droplet sizes inside acoustic wave to find no high optimal power. The optimal regimes below were analyzed and calculated for the ensemble of cloud droplets: the optimal frequency (*f*) should be low enough with an appropriate decrease in the acoustical power, *Q*. The power decrease tends to weight and size minimization these are desirable from a real utilization in helicopter. Typical clouds have droplet radii within the range from $r \approx$ 1 - 50 μm, and the objective for the acoustics is the additional motion of the droplet ensemble in receiving greater droplets with radii $r \geq 100$ μm. Known model (8-9) was developed earlier for small droplet assembles [11], it gave good description for special media like smoke or industrial fogs where radii r ≤ 1 μm are small. The Stokes friction for air flow at the droplet's surface provided particle's motion inside acoustic wave, which is physical core of this model. For more large cloud droplets this model wrong, because is predicts the equality for the velocities of air V_a and droplet V_w for small frequencies ω, see the first term in right side of result equation (9). The acoustic pressure is $P(t) = P_a \cdot \sin(\omega t)$, ω is the circular frequency of the acoustic wave This model present equations with their solutions, as follows:

$$m\frac{dV_w}{dt} = 6\pi\eta r\left(V_a - V_w\right) \qquad (8)$$

$$\tau\frac{dV_w}{dt} + V_w = V_{a,\max}\sin(\omega t)$$

$$V_w = \frac{V_{a,\max}\sin(\omega t - \varphi)}{\sqrt{1+\omega^2\tau^2}} + \frac{\omega\tau V_a}{1+\omega^2\tau^2}\cdot\exp\left(-\frac{t}{\tau}\right) \qquad (9)$$

There relaxation time is $\tau \approx 0.22 \cdot \rho_w \cdot r^2/\eta$, $\tau \sim 10^{-7}$s for particles radius 0.1 μm, but $\tau \sim 10^{-5}$ s for r = 1 μm, it provides zero in the second term in right side of (9) for

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low frequency then t ~ π/ω. As a result, the medium/droplet delay $\varphi = \arctan(\omega\tau)$ is small here when $\tau\omega << 1$. This model was developed for small particles then $r << 1$ µm was the norm, but frequency was in *kHz* range. Therefore, using this model we found that the velocity amplitude of driving cloud droplets becomes equal to the speed of the air molecules $V_w \approx V_a$ in (9). Of cause, this is an incorrect model for large-sized droplets in clouds which need much driving force for their big masses.

The new model is suggested here for large droplets inside clouds. Air molecules bombard great droplet surface at ½ front side to pass their impulse for droplet motion, the result is the creation of the driving force. It provide droplet vibrations back and forth in the acoustic wave; moves the droplets with an amplitude *L* that has a maximal displacement during a time for half the period, as follows:

$$L_{\max} = \int_0^{\pi/\omega} V(t)dt \qquad (10)$$

there *L* is the droplet amplitude, but *V(t)* is its velocity. The modern complete model of one-dimensional vibration for a cloud droplet in a viscous medium can be found, for example, in [27-28], as follows:

$$\left(\frac{4\pi r^3}{3}\rho_w + f_2\right)y'' + (f_0 + f_1)y' = F\cdot\sin(\omega t) \qquad (11)$$

$$f_1 = 6\pi\eta_a r + 3\pi r^2\sqrt{2\eta_a\rho_a\omega} \qquad (12)$$

$$f_2 = 3\pi r^2\sqrt{2\eta_a\rho_a/\omega} + \frac{2}{3}\pi\rho_a r^3 \qquad (13)$$

where are water and air density are ρ_w, and ρ_a; η_a is medium viscosity, and *F* is a driving force amplitude. The coefficients f_1 and f_2 correspond to the medium counteraction and are proportional to the speed and acceleration, respectively; f_0 corresponds to the inner mechanical losses that are, in reality, small. One can see that the Stokes's term, the first term of f_1 (12) is introduced into the motion equation (11). However, the second term in (12) provides the drag. The second part of f_2 characterizes the vibration of the joint mass of the medium surrounding a droplet, the first term in (13) corresponds to acoustic radiation losses. The solution of mentioned system (11-13) for the droplet velocity $V(t) = y'$ provides the following equation:

$$V = C\cdot\exp(-2ht) + \frac{B}{(2h)^2+\omega^2}\left[2h\cdot\sin(\omega t) - \omega\cdot\cos(\omega t)\right] \qquad (14)$$

where normalized acted force is $B \approx F \backslash m \approx F \backslash (1.333\pi r^3\rho_w)$. The attenuation para-meter is h which follows from the initial equation $V=0$ then $t=0$; also the integration-resulted term *C* is as follows:

$$h = \frac{f_0 + f_1}{f_2 + 4\pi r^3\rho_w/3}, \qquad C = \frac{B\omega}{\left[\omega^2 + (2h)^2\right]} \qquad (15)$$

The droplet amplitude for half of the period of acoustic waves is *L*, the final solutions are as follows:

$$L = \frac{B}{\omega^2 + (2h)^2}\left\{2\frac{2h}{\omega} - \frac{\omega}{2h}\left[\exp\left(-\frac{2h\pi}{\omega}\right) - 1\right]\right\} \qquad (16)$$

The driving force, *F*, should be determined at this point in order to obtain the numerical calculations, and it is necessary to set the predominant mechanism for the counteraction of acoustics using the weighted droplet in air to add the vibration. Here we assume the bombardment of the front surface of the large droplet by small air molecules; as well as the impulse transfer required to move the droplet to another location. The simplest formula of such a physical model describes the impulse transfer, $F\cdot\Delta t = \Delta p$. Side surface effects can be neglected for large droplet objects according to the next chapter consideration. The affecting force increases in proportion to the area of the front surface is ~ $2r^2$. However, the droplet mass grows with radius as ~ r^3 that is mass driving is predominate. Molecule forward or back motions occur during the time of half period of the wave $t_{1/2} = \pi/\omega = 0.5f^{-1}$. The volume of air molecules in the front of the droplet is $U_N = S\cdot\int_0^{\pi/\omega} V_a(t)dt = \pi r^2 V_a 2/\omega$, but the cross-section of water droplet is $S = \pi r^2$. The complete mass for air molecules in this volume is $M_a \approx N\cdot 28\cdot m_p\cdot U_N$. Here Avogadro's constant, and taking molecular mass for nitrogen is $2\cdot 14 m_p$. We put to use for estimations the average molecule's velocity in acoustical wave $V_a/2$. Driving force in acoustic wave according to second Newton's law could be found $F = M_a\cdot\Delta V/\Delta t \sim M_a\cdot V_a/t_{1/2}$, and it corresponds to the next equation:

$$F \approx (28 m_p N)\cdot r^2 V_a^2 = C_F\cdot r^2 V_a^2 \qquad (17)$$

where the coefficient is $C_F \approx 1$ in the SI system. The acoustic pressure, *P*, in the sound wave; the acoustic power, Q; the velocity, V_a, of the air molecules; their displacement, L_m; and the speed of sound C_a are connected as follows:

$$V_a = \sqrt{\frac{2Q}{\rho_a C_a}}, \quad P_a = \rho_a C_a V_a, \quad L_m = \frac{1}{2\pi f}\sqrt{\frac{2Q}{\rho_a C_a}} \qquad (18)$$

Below we introduce the pulse power *J*, then $Q = J\cdot f$. After previous unification, the driving force or large droplets in the acoustic wave is as follows:

$$F \approx \left(\frac{2C_F}{\rho_a C_a}\right) r^2 J \cdot f \text{ , } B = F/m_w \quad (19)$$

The droplet mass is $m_w = 4\pi r^3_w/3$, the droplet give the amplitude $L(f,r)$ in the from $L(f,r)$:

$$L(f,r) = \frac{Jf}{r} \cdot \frac{C_{F2}}{(2h)^2 + (2\pi f)^2} \cdot \left\{ \frac{2h}{\pi f} + \frac{\pi f}{h} \cdot \left[1 - \exp\left(\frac{-h}{f}\right) \right] \right\} \quad (20)$$

There coefficient is $C_{F2} = \dfrac{3C_F}{2\pi \rho_w C_a \rho_a}$.

Numerical calculations and the results are presented in Figure 2 according to proposed model (10-20). Figure 2 demonstrates examples for some optimized regimes for three acoustical ranges, as follows: (1) f = 20 Hz with lowest power Q = 175 W/m^2; (2) f = 50 Hz with Q = 800 W/m^2 and (3) f = 100 Hz with Q = 2500 W/m^2. Additional analysis were performed using the introduction of appropriate altitude changes relative to the main physical parameters in the model, as follows: air density (ρ_a), viscosity (η), sound velocity (C_a), and air temperature depending on km-altitudes. A decrease in necessary acoustic power using the 2 – 6 km location of cloud with sound source within the atmosphere was observed, so calculations indicated a 10-15% increases for the amplitude values, L, according to the acoustics applied to the cloud drops directly at a altitudes of 6 km above the ground. For a typical cloud droplet, the estimations indicate that gravity is negligible small (0.1%), as well as the drag force, due to the friction of air flow at the surface of the droplet.

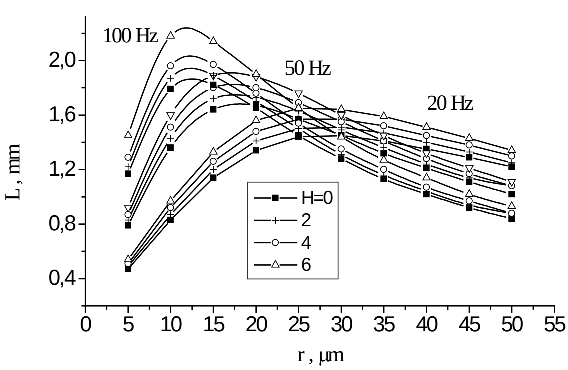

Figure 2 : Vibration amplitudes L for droplets radii 5 – 50 µm for their location at altitudes H = 0, 2, 4, 6 km. The regimes are: f = 100 Hz and Q = 2.5 kW/m^2; f = 50 Hz and Q = 800 W/m^2; f = 20 Hz and Q = 175 W/m^2

Now let's estimate the optimal average distance that should allow the droplets to collide. An average number concentration of droplets in a cloud occurs in the range from $N \sim$ 60 – 1000 cm^{-3} and more according to various measurements, see for example [13]. Here we assume that $N \sim$ 500 cm^{-3} specifies the individual volume occupied by a weighted drop 1/N, and that its average distance is $L_i \sim N^{1/3} \approx$ 1.26 mm. The proposed regimes at Figure 2 provide necessary amplitudes for the typical ensemble of cloud droplets. The time requirement is L_i / r ≈ 1260/10 = 2 minutes or more to provide coalescence probability. The probability of the complete or partial amalgamation for two collision rainy droplets depends both on their sizes and velocities as listed below. The irradiation time should be more longer for low frequency affects.

V. The Acoustic Technique to Facilitate Precipitations

Sirens are believed to be most suitable generators for powerful sound in air medium [29-31]. The variant of siren is composed of a fixed stator with small holes in the periphery, and it has a stator located inside of the rotating rotor with the same numbers of holes. The holes of the rotor and stator periodically overlap, so the compressed air comes out from siren core from time to time. Outgoing air kicks to the walls of the resonator vibrating on own resonance frequency to put acoustical signal to the outer media. The siren frequency is given by the number of holes (or teethes) z, and the number of rotor circulation per second, n_c, as follows $f = zn_c$. For example, when n_c = 12.5 c^{-1} and z = 8, the frequency is f = 100 Hz; or the n_c = 6.25 c^{-1} then frequency is f = 50 Hz. This frequency is related to the rotor speed and the fundamental mode of the resonator to maximize power output for the signal. The siren was constructed and tested in experiments, so the frequency change of the rotation speed is done by coupling the motor and the transformer with the variable voltage in order to tune speed for experiments [9].

Let's describe below the features of Bessel-form resonator to get pure monochromatic wave by high spectrum selection into fundamental mode of resonator. The idea is that the shape of the optimal resonator for a siren should have Bessel-formed walls to maximize the power of acoustic radiation to a fundamental harmonic within output beam. The fundamental harmonic distribution for energy in the radial direction is $J_0(kr)$ of propagated fundamental wave. The sound frequency is f, and sound speed $C_v = 340$ m/s, for wavelength (Λ), when f = 100 Hz we have: $\Lambda = C_v/f = 3.4$ m, the wave vector $k_0 = 2\pi/\Lambda = 2\pi f/C_v$. The first zero-solutions for the Bessel function is $x_0 = 2.404826$ for $J_0(k_0 r_0) = J_0(x_0) = 0$, such that the reflector's output radius, r_0, meters, can be modified to the formula $k_0 r_0 = x_0 = 2.404826$, and as follows:

$$r_0(f) = \frac{x_0}{2\pi \cdot f} \cdot C_v \approx \frac{130}{f} \quad (21)$$

The calculated data for the outlet radiuses of Bessel's resonators are: $f = 100$ Hz needs $r_0 = 1.3$ m; $f = 50$ Hz needs $r_0 = 2.6$ m and etc.

At the outlet of proposed reflector (at $x_0 = 2.4$), the edges should be folded outwards as a bell-shape to avoid edge diffraction with appropriate transfer of the radiated power into the higher harmonics. Technically, such a reflector could be manufactured using long and narrow strips of sheet of metal; strips could be assembled according to the principle of the fan and held together by transverse belts. The output siren powers can be estimated using data at Fig.2. These data should be multiplied to the output resonator square $S_{res} = \pi r_0^2$ then resonator output radius r_0 was calculated from equation (21), as follows:

$$Q_0 = 2.5 \cdot S_{res} \approx 13 \text{ kW then } f = 100 \text{ Hz}; \; Q_0 = 0.8 \cdot S_{res} \approx 21 \text{ kW then } f = 50 \text{ Hz} \quad (22)$$

There are sirens with similar output power [30], and manufactured siren in [9] had power up to $Q_0 \approx 4$ kW. The experimental tests in mist areas demonstrate the coagulation effect, but the siren power should be increased by the factor 3 for $f = 100$ Hz according to (22). The simple way to do it is the increase of the number of holes by factor 3 or the same increase of hole's surface, so radiuses should be increased up to $1.7 \cdot r$. The air output flow near siren holes is $V \approx 300$ m/s and summarized holes surface $S_0 = 3$ cm^2. Calculation show that the siren needs the air pump about ~ 0.1 m^3/s. Let's consider ways of improving of acoustical effect and/or acoustic technique. To begin with we note, that the siren will be more effective then the average number N_{cl} of droplets in a cloud is higher then considered here number $N = 500$ cm^{-3}, so let's assume $N_{cl} \sim 1000$. The average droplet distances will be $L_m \sim 1$ mm and according to previous estimation: $L_m \sim N^{1/3} \approx 1$ mm. The vibration amplitude from equation (20) is linearly proportional to the acoustic power necessity J. This means that such cloud has small output acoustic power from siren according to (22) and Fig.2: $Q_0/2 \approx 6.5$ kW.

Also considered here is the type of moved siren with air inside pumped by the strong oncoming of the air flow through additional cylinder with compression system [31]. Such device can be located at airplane and oriented according to its axis, so incoming air flow is captured by compressed system to put air to sired rotated core, and also to the Bessel-resonator through summarized holes surface S_0. The axis of Bessel-form resonator should be oriented at opposite to moving direction. The model and calculation show high efficiency to get air pumping [31] inside moved siren cylinder then airplane velocity is not supersonic.

The following acoustic action utilizes a helicopter. Small airplane is typically used in clouds for precipitation enhancement and so hygroscopic particles distributed into the cloud from an airplane. Note that a helicopter can serve this purpose much better, because it is less speedy and more maneuverable then an airplane. The helicopter has the following advantage in comparison to the airplane. The rotor blade of the helicopter rotates with a sufficiently large angular velocity, so the linear velocity at the end of each blade reaches the speed of sound. Typical helicopters blade has a length of 10 meters and its partial speed varies linearly from 0 to 300 m/sec, but suppose helicopter is moving forward with some speed, for example 100 km/h = 360 m/sec then supersonic motion of one blade is produced in small time periods. This effect takes place because there are the same directions of helicopter motion and one of its blades moving in the same direction with its own speed. It means that each of the blades overcomes the supersonic regimes producing the shock wave. The shock wave has a steep front and big difference of pressure and temperature comparable to surroundings. So such wave pushes the droplets to coalesce effective and also provides a rapid condensation. Fast condensation inside the shock wave can be seen in many photographs when airplane breaks the sound barrier.

VI. Conclusion

In this paper two staged approach for free atmosphere CO_2 purification is proposed. To begin with alkaline reagents were injected into natural clouds in order to increase their pH-level up to 10 or 11. Enhanced precipitation facilitated for the carbon transport from atmosphere to the ground. It was shown by corresponding calculations that there is a considerable increase of the gas/water interface for CO_2 absorption; and grass photos indicates the positive plant's reaction to water at initial $pH = 12$. Note that the proposed acoustic method is up to date and does not require extensive support. The models and calculations are presented for the regimes of acoustic power that are required to implement inside cloud according to proposed new low-frequency model. Acoustic method provides fast droplets coalescence inside nature clouds and sedimentation "to get rain at the right time". Additionally, artificial rains facilitate air purification and climate corrections. The resulting effect can compensate for annual carbon emission by applying method at 0.4 % – 0.1 % of the Earth surface.

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Rangeland Suitability Evaluation for Livestock Production using Remote Sensing and GIS Techniques in Dire District, Southern Ethiopia

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Abstract- Management of complex ecosystems such as rangelands needs adequate knowledge to consider its capability for sustainable utilization. Land suitability analysis is needed to make proper land-use planning. GIS and Remote Sensing techniques offer a convenient and powerful platform to integrate spatially complex and different land attributes for performing land suitability analysis. The present study was intended to analyze and map suitable areas for livestock production in Dire district using remote sensing and GIS techniques. The study made use of Landsat TM 2011 remote sensing satellite image for land-use/land-cover analysis, and Multi Criteria Evaluation in a GIS environment to come up with the final suitability map.

Keywords: *GIS, livestock, multi criteria evaluation, rangeland, remote sensing, suitability analysis.*

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RANGELANDSUITABILITYEVALUATIONFORLIVESTOCKPRODUCTIONUSINGREMOTESENSINGANDGISTECHNIQUESINDIREDISTRICTSOUTHERNETHIOPIA

Rangeland Suitability Evaluation for Livestock Production using Remote Sensing and GIS Techniques in Dire District, Southern Ethiopia

Berhanu Keno Terfa α & K. V. Suryabhagavan σ

Abstract- Management of complex ecosystems such as rangelands needs adequate knowledge to consider its capability for sustainable utilization. Land suitability analysis is needed to make proper land-use planning. GIS and Remote Sensing techniques offer a convenient and powerful platform to integrate spatially complex and different land attributes for performing land suitability analysis. The present study was intended to analyze and map suitable areas for livestock production in Dire district using remote sensing and GIS techniques. The study made use of Landsat TM 2011 remote sensing satellite image for land-use/land-cover analysis, and Multi Criteria Evaluation in a GIS environment to come up with the final suitability map. In this study, factors such as rainfall, land-use/land- cover, soil, slope, access to water, veterinary service and livestock market center were considered as factors. The result of the suitability analysis revealed that 5.6 %, 4.9 %, 5.4 %, and 10.1 % of study area was highly suitable for cattle, sheep, goat and camel, respectively; 44.75 %, 44.15 %, 45.5 % and 58.6 % of the land was classified as moderately suitable for cattle, sheep, goat and camel, respectively. Furthermore, 45.7 %, 46.5 %, 51 % and 31% of the land was classified as marginally suitable for cattle, sheep, goat and camel, respectively, and 4 %, 4.5 %, 1.1 % and 0.4 % was not suitable for cattle, sheep, goat and camel, respectively. Thus, the study showed that the large area of the rangeland in Dire district is only marginally suitable (with major limitations) for livestock production. Therefore, implementation of appropriate rangeland management plan in the district is essential.

Keywords: GIS, livestock, multi criteria evaluation, rangeland, remote sensing, suitability analysis.

I. Introduction

Land suitability analysis is the evaluation and grouping of specific areas of land in terms of their suitability or capability for a defined use. It involves the application of criteria to the landscape to assess where land is most and least suitable for a particular purpose. The suitability of a given land is based on its natural ability or the biological productivity for and its applied a specific purpose. Analyzing suitability is mainly based on the land qualities satisfying the requirements of the land-use.[1] Thus, the common way of determining land quality from land characteristics is
determining land quality from land characteristics is
mainly by assessing and grouping the land types in to different classes according to their values.[2]

A number of technological developments have facilitated the implementation of land evaluation principles and models. In order to incorporate different land attributes that differ spatially and to identify the best suitable land-use, Geographic information System (GIS) has proved to be a useful tool.[3] The powerful query, analysis and integration mechanism of GIS makes it an ideal scientific tool to analyze data for land-use planning. Management of natural resources based on their potentials and limitations is essential for development of rangeland on a sustainable basis. Today, GIS is a tool that can assist a community to plan and to support the information management during the rangeland production process, while ensuring balance between competing resource values. It can enhance the accessibility and flexibility of information and can improve the linkages and understanding relationships between different types of information.[4]

Land resource is limited in nature and its use is not only determined by the user but also by the processes of the land, its characteristics to sustain the production of required goods and services. Inappropriate land-uses lead to inefficient exploitation and destruction of the land resource, leading to poverty and other social problems. Society must ensure that land is not degraded and that it is used according to its capacity to satisfy human needs of the present and future generations, maintaining the ecosystem processes. Part of the solution to the land-use problem is land evaluation in support of rational land-use planning and appropriate and sustainable use of natural and human resources. Most pastoralists occupy a naturally dry environment, which is unsuitable for conventional rain-fed agriculture.[5] Yet, this very same land is ideal for extensive livestock production, the kind of life style that pastoralists are so familiar at managing. In such a fragile setting, proper land management is an absolute necessity. Until very recently, the Borana rangeland of Southern Ethiopia was considered to be

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one of the best grazing lands in east Africa.[6] Since the early 1980s, there is evidence that the system in the Borana rangeland is experiencing a decline in productivity, associated with periodic losses in cattle populations.[7] This was probably related to extreme climate change and variability, changes in land-use, animal diseases, bush encroachment, suppression of fire that resulted in the proliferation of bush encroachment, a general decline in forage production and over estimation of the grazing capacity.[8,9] The Dire district is one of the Borena Zones, which is situated in arid and semi-arid lands (ASALs), which experiences low and erratic rainfall and high temperature that hinder any significant crop production. However, high population growth has resulted in increased demand for arable land leading to reduced amount of land for natural grazing and forage production. Increasing land-use conflicts, which could lead to fast depletion of land resources, land degradation and bush encroachment is also associated with the population growth, and human activities have exerted excessive pressure on the extents of grazing lands.

Locating suitable areas for livestock production using spatial models of GIS would be indispensable to improve livestock productivity.[10] To get the maximum benefit out of the land, proper use for specific purposes is inevitable. Therefore, the most important criterion for sustainable animal production is the selection of appropriate land areas, which meet biophysical, environmental and socio-economic restrictions. Hence, it is of paramount importance to identify suitable land for livestock production, which enhances resilience of the environment. Although livestock production is a vital component of agricultural systems, it has so far been overlooked in integrated land and water management for food security in poverty alleviation strategies. There is a need for research and capacity building to understand the complex issues of water, livestock and land management of the district, so as to enhance national and local capacity to deal with water and livestock issues to enhance food security, reduce poverty and speed up national economic developments. The present study was aimed to evaluate and map suitable land areas for livestock production in Dire district using GIS and remote sensing techniques.

II. The Study Area

The present study area is bounded by latitudes 4° 37' 0" – 4° 37' 10"N and longitudes 37° 56' 0" –38° 31' 0" E in Borena Zone, Oromia Regional State, Ethiopia, and covers a total area of 3921 km2 (Fig. 1). The altitude ranges from 750 to 1870 m asl and the topography consists of isolated mountains, valleys and depression. This area is considered as a good representative site of the Borana rangelands of Ethiopia.

The rainfall of the study area ranges between 300–900 mm with bi-modal monsoon rainfall type, where 60 % of the annual rainfall occurs during March to May and 40 % between September and November.[11] The period from June to September is characterized by heavy cloud cover, mist and occasionally short showers, while the main dry season occurs from November to March with high evaporation (BLPDP, 2004). The overall average temperature ranges from an annual mean minimum of 13.3°C to annual mean maximum of 29.5° C.

The general vegetation type of the study area is *Acacia* savannah, the major trees being *Acacia drepanolobium* in black cotton soil, and *Acacia brevispica* and *Acacia horrida* on the slopes. According to,[12] *Commbertum Terminalia* and *Acacia commiphora* woodlands characterize the lowlands of Borana zone. Bushlands and thickets, which cover major parts of the lowlands are dominated by *Acacia* and *Commiphora* species. Besides, species of the genera *Boscia, Maerua, Lannea, Balanites, Boswellia* and *Aloe* are common in the study area.[13]

a) Methods

b) Rangeland suitability analysis

In the present study, four environmental land parameters were considered such as land-use/land-cover, soil, slope and rainfall. Socio-economic parameters were access to drinking water, veterinary services and access to market. Assessment of these parameters provides information about the limitations of the land for agricultural development.

i. *Environmental factor analysis*

For the present study, the following four environmental land parameters were considered: soil, slope, rainfall and land -use/land-cover. Assessment of these parameters provides information about the limitations of the land for agricultural development.

a. *Land-use/ land-cover*

Cloud free LANDSAT TM image (path 168 and row 057) acquired in January 2011 during the dry season was analyzed to classify the land-use/ land-cover of the study area. Geometric correction and image enhancement were conducted using ERDAS Imagine 9.2. Unsupervised classification of the study area was performed prior to field visit and representative points thought to represent the various land-cover classes were marked using GARMIN GPS during field visit. Using ERDAS Imagine 9.2, 24 *in-situ* data points were selected from each classified group to be checked in the field. Later, some points were added in the field for land-use/land-cover identification from the image. The overall accuracy and the Kappa value of field data vs automated classification results were 86.05% and 0.84, respectively. False color composite was prepared using the order of 4, 3, 2 band sequence and then different enhancements were made to increase the visual interpretation of the image. Based on the field check points, supervised classification approach with the maximum likelihood classifier system was applied to improve the accuracy of the land-use classification of the image. According to the current land-use/land-cover analysis, eight classes such as Forest, Open bushland, Dense bushland, Open shrubland, Dense shrubland, Grassland, Farmland and Bareland were made.

b. *Soil*

For this study, soil mapping unit of Dire District was used as one of the parameters for suitability analysis. Physical properties of soil were considered for interpretation and analysis. FAO Soil Classification was used in the Suitability Modeling.[14]

c. *Slope*

Slope was generated from SRTM data in GIS platform using Geostatistical Analyst's surface analysis technique.

d. *Rainfall*

The mean monthly average rainfall of six stations (1 within the study area and 5 from the adjoining districts) for 16 years was collected from National Meteorological Services Agency (NMSA), Ethiopia. Subsequently, a surface was interpolated from the points data in a GIS platform using Geostatistical Analyst's ordinary Kriging technique.

ii. *Socio-economic factor analyses*

Socio-economic factors in the rangeland includes road and transport condition, communication system, market outlets, veterinary clinics and services, health centers/health posts, abattoirs, skins and hides collecting and preserving systems, communication and training systems. The highly managed rangelands need to have a range management station office to serve in case of emergencies such as disease outbreaks, executing, monitoring and reporting day to day activities. In this study, three infrastructural indicators were used namely access to drinking water, access to veterinary services and access to market.

a. *Distance to drinking water resource*

A map of distance to water was obtained first by combining artificial water point in water map. The water map was rasterized and then a distance map was calculated from it.

b. *Distance from veterinary services and market center*

This was calculated by buffering from the veterinary and market center points and rasterized to reclassify and a distance map was calculated from it.

All the above mentioned parameters have been considered for the analysis towards the identification of suitable areas for livestock production, they were mapped separately. Each of the criteria map displays land suitability measured on ordinal scale for land suitability and assigned values of high, medium and low suitability depending on land attributes.

c) *Factor/Criteria rating*

Factor ratings are sets of values which indicate how well each factor/criterion is satisfied by particular conditions of the corresponding land quality. Thus, as a first step, compilations of the livestock production requirements that will be considered in the evaluation were made. In the present study, both bio-physical and infrastructural parameters of the area were used as factors for suitability analysis. Then, the second stage is to decide on the factor ratings for each livestock species. Factor ratings were made in terms of five classes such as highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1), and permanently not suitable (N2). All the above mentioned parameters were considered for the analysis for the identification of suitable areas for livestock production.

d) *Criteria standardization*

The module named reclass (in ArcGIS environment) for standardization/reclassification of the factors was used. Thus, each factor has an equivalent measurement basis before any weight is applied. Accordingly, all the factors used for this study were reclassified into five classes (S1,S2, S3, N1 and N2) with the range of values 1 to 5, where the value 1 represents the most suitable and 5 represents the least suitable for the factors considered.

e) *Assigning criterion weights*

In the procedure for multi-criteria evaluation (MCE), it is necessary that the weights sum to 1. Accordingly, in IDRISI, the weight module utilizes the pair-wise comparison technique to help develop a set of factor weights that will sum to 1. In pair-wise comparison matrix, factors are compared two at a time in terms of their importance related to the stated objective. The matrix is symmetrical and only the lower triangle actually needs to be filled in. The remaining cells are the reciprocals of the lower triangle. After all possible combinations of two factors were compared, the module calculates a set of weights and a consistency ratio. This ratio indicates any inconsistencies that may arise during the pair-wise comparison process. The module allows repeated adjustments to the pair-wise comparisons and reports the new weights and consistency ratio for each interaction.

The combination procedure follows the conventional scheme for GIS based MCDA. It involves three main steps. First, the criterion maps were standardized/ reclassified using Spatial Analyst's Reclassify tool. Thus, each factor has an equivalent measurement basis before any weights are applied. Accordingly, all the factors used for this study were reclassified into five classes (S1, S2, S3, N1 and N2) with the range of values 1 to 5 as explained earlier. This step is necessary because the criterion maps contain the ordinal values (high, medium and low) that indicate the degree of land suitability with respect to a particular criterion (criteria standardization), and the derivation of the relative criterion importance using the pair-wise comparison method. The criterion weights are automatically calculated once the pair-wise comparison matrix is entered in IDRISI-AHP weight derivation module. Finally, the criterion weights and the standardized criterion maps were combined/aggregated by means of weighted overlay technique analysis. Figure 2 shows methodological flow chart.

III. Results

a) Parameter-wise suitability of environment

i. *Land-use/land-cover*

A major factor curtailing the suitability of rangeland in the study area was its dominance by dense bush- and shrub- lands that produce leaf biomass of low palatability to cattle and sheep. It was also responsible for hindrance for the movement of livestock while foraging. Land-use/land-cover suitability analysis revealed that a large a portion of the area (33.12 %, 1298.7 km^2) is marginally suitable for grazers (cattle and sheep) and 47.34 % (1856.13 km^2) for browsers (goat and camel). A relatively small area of ~16.9 % rangeland is highly suitable for cattle, sheep and goats and 32.35 % for camels. Out of the total rangeland area in the District, 16.9 % (662.83 km^2) is highly suitable for grazers (cattle and sheep), moderately suitable 32. 35 % (1268.5 km2) for goats and 19.6% (768.52 km^2) for camels. Further, of the total rangeland area, 30.27 % (1186.8 km^2) fell into currently not suitable category for cattle and sheep, while 0.11% (4.15km^2) fell into permanently not suitable category for goats and camels and a meager 0.11 % (4.15km^2) also into the same category for all livestock (Table 1).

ii. *Rainfall suitability*

Rainfall suitability analysis showed that 100 % of the rangeland in the district fell under highly suitable category for camels, whereas the same fell into moderately suitable category for cattle, sheep and goat (Table 1).

iii. *Soil and slope suitability*

Soil suitability analysis revealed that the district is more favorable for all livestock categories with 54.6 %, 10.1 %, 33.24 % and 2.1 % of the rangeland being highly suitable, moderately suitable, marginally suitable and currently not suitable, respectively, leaving no area under permanently not suitability category (Table 1). Slope suitability analysis reflected that a large area of the district is relatively flat and as such over 80% of the rangeland area is highly suitable for all livestock categories together. However, about 3.75 %, 3.16 %, 3.44 % and 3.1 %, 3.8 %, 5.85 % and 4.1 % of this entire area is either currently or permanently not suitable for cattle, sheep, goats and camels, respectively, while ~3 % goes for tourism and wildlife habitats (Table 1, Fig. 3).

iv. *Distance from water resources, livestock market and veterinary services*

Suitability analysis of distance from water resources for different livestock categories revealed that 39.8 % and 55.1 % of the rangeland area is highly suitable for cattle and camels, respectively, and a proportion of 17.8 % for sheep and goats (Table 1). Further, 43.44 % of the area is moderately suitable for cattle. Large portion (44.85 %) of the area is found not suitable for sheep and goats. The district is constrained with the distance of the rangeland from water resources in the case of sheep and goats. Distance from livestock market suitability analysis showed that ~34.4 % of the rangeland area is moderately suitable for cattle and camels, while 47.32 % is currently not suitable for sheep and goats. As regards veterinary service suitability, ~40.1% of the district is moderately suitable for all livestock categories.

Thus, the results portray that biophysically the areas with flat to gentle slope, grassland and areas with mean annual rainfall >800 mm were highly suitable for cattle and sheep production. Availability of water, animal health services and livestock market within 5, 10 and 15 km distance, respectively, were found highly suitable for cattle, while areas with a distance of <5 km to water source as well as veterinary services together with <7 km of distance from market were identified as highly suitable for sheep and goat production.

Table 1 : Factor-wise suitability classes with respective area of coverage for cattle, camels, sheep and goats

		Factors													
Livestock	**Suitability**	**LU/LC (km^2)**	**%**	**RF (km^2)**	**%**	**Slope (km^2)**	**%**	**Soil (km^2)**	**%**	**Access to Water (km^2)**	**%**	**Access to veterinary service (km^2)**	**%**	**Access to Market (km^2)**	**%**
Cattle	S1	662.83	16.9			3137.7	80	2140.5	54.6	1560.7	39.8	819.5	20.9	1329.1	33.9
	S2	768.52	19.6	3921	100	382	9.74	395.6	10.1	1703.5	43.44	1573.8	40.1	1348.7	34.4
	S3	1298.7	33.12	-	-	134	3.42	1303.6	33.24	489.4	12.5	873.8	22.3	702.5	17.9
	N1	1186.8	30.27	-	-	147.7	3.75	81.3	2.1	167.4	4.27	653.9	16.7	540.2	13.8
	N2	4.15	0.11	-	-	119.6	3. 1	-	-	-	-	-	-	-	-
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Camels	S1	1268.5	32.35	3921	100	3137.7	80	2139.7	54.6	2161.4	55.1	819.5	20.9	1349.1	34.4
	S2	768.52	19.6	-	-	382	9.74	396.7	10.12	1101.7	28.1	1572.8	40.1	1338.7	34.4
	S3	1856.13	47.34	-	-	137.4	3.51	1303.4	33.24	607.6	15.5	874.8	23.3	706	18
	N1	23.7	0.6	-	-	124	3.16	81.2	2.1	49.3	1.3	653.9	16.7	527.2	13.44
	N2	4.15	0.11	-	-	139.9	3. 8	-	-	-	-	-	-	-	-
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Sheep	S1	662.83	16.9			3137.7	80	2139.7	54.6	698.6	17.8	819.2	20.9	635.7	16.21
	S2	768.52	19.6	3921	100	420.8	10.7	396.7	10.12	862.1	22	1573.3	40.1	713.4	18.2
	S3	1298.7	33.12	-	-	135	3.44	1303.4	33.24	601.8	15.35	874.1	22.3	716.3	18.27
	N1	1186.8	30.27	-	-			81.2	2.1	1758.5	44.85	653.7	16.7	1855.6	47.32
	N2	4.15	0.11	-	-	227.5	5.8 5	-	-	-	-	-	-	-	-
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Goat	S1	768.52	19.6			3137.7	80	2139.7	54.6	698.6	17.8	819.2	20.9	635.7	16.21
	S2	1268.5	32.35	3921	100	516.5	13.2	396.7	10.12	862.1	22	1573.3	40.1	713.4	18.2
	S3	1856.13	47.34	-	-	107	2.73	1303.4	33.24	600.8	15.35	874.1	22.3	716.3	18.27
	N1	23.7	0.6	-	-			81.2	2.1	1758.5	44.85	653.7	16.7	1855.6	47.32
	N2	4.15	0.11	-	-	150.8	4. 1	-	-	-	-	-	-	-	-
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

LU/LC: Land-use/ land-cover, RF: Rainfall, S1: Highly suitable, S2: Moderately suitable, S3: Marginally suitable, N1: Currently not suitable, N2: Permanently not suitable

v. *Overall environmental suitability*

Results of environmental factors (land-cover, rainfall, soil and slope) analysis showed that the District is marginally or moderately suitable for livestock production (Table 2, Fig. 4). Of the total area, 41.57 %, 41.57 %, 51.7 % and 45.46% of the area is marginally suitable while 40.39 %, 40.29 %, 40.24 % and 33.3 % of the area is moderately suitable for cattle, sheep, goats and camels, respectively. In contrast, only a small area is highly suitable for cattle (8.21 %), sheep (8.4 %), goats (7.42 %) and camels (20.76 %). Further, a small extent of the area, though scanty for the requirement of browsers (goats and camels) than grazers (cattle and sheep) also fell into currently not suitable and permanently not suitable categories.

Table 2 : Land suitability classes for livestock production based on environmental factors

Suitability Classes	Livestock category							
	Cattle		Sheep		Goats		Camels	
	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)
Highly suitable	321.75	8.21	329.38	8.4	291.11	7.42	814	20.76
Moderately suitable	1583.5	40.39	1579.7	40.29	1578.02	40.24	1306.85	33.33
Marginally suitable	1629.9	41.57	1629.71	41.56	2026.94	51.7	1782.35	45.46
Currently not suitable	385.85	9.84	382.21	9.75	24.93	0.64	17.8	0.45
Permanently not suitable	0.58	0.01	0.63	0.02	0.46	0.01	-	-
Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

vi. *Socio-economic suitability*

The suitability analyses results based on socio-economic factors (access to water, livestock market and veterinary services) revealed that the District is moderately suitable for camel and marginally suitable for cattle, sheep and goats (Table 3, Fig. 5). Rangeland of 36.3 %, 27.9%, and 44.3 % extent are moderately suitable for cattle, camels and sheep/ goats, respectively. Similarly, 37.5 %, 38.6 % and 23% of the areas are marginally suitable for cattle, sheep/ goats and camels, respectively. Further, small areas are also highly suitable for small ruminants (sheep and goats 8.25 %), cattle (13.8%) and camel (26.2). But, an area of 25.25 %, 12.3% and 6.5 % fell into currently not suitable category for small ruminants (sheep and goats), cattle and camels, respectively.

Table 3 : Land suitability classes for livestock production based on socio-economic factors

Suitability Classes	Livestock category							
	Cattle		Sheep		Goats		Camels	
	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)
Highly suitable	539.8	13.8	323.4	8.25	323.4	8.25	1029.2	26.2
Moderately suitable	1423	36.3	1093.2	27.9	1093.2	27.9	1741	44.3
Marginally suitable	1476.7	37.5	1514.3	38.6	1514.3	38.6	897.9	23
Currently not suitable	481.5	12.3	990.1	25.25	990.1	25.25	252.9	6.5
Permanently not suitable	-	-	-	-	-	-	-	-
Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

vii. *Final suitability analysis*

A wide area of the rangeland in the District is classified as marginally suitable category for cattle, sheep and goats, while about half of the area fell under moderately suitable category for camels. Further, 45.7 %, 46.45 %, 51 % and 30.9 % of the rangeland were found marginally suitable for cattle, sheep, goats and camels, respectively. Similarly, 44.75 %, 44.17 %, 42.52 % and 58.6 % of the land is recognized as moderately suitable category for cattle, sheep, goat and camels, respectively, while small portions of 4 %, 4.48 %. 1.11 % and 0.38 % of the area are currently not suitable for cattle, sheep, goat and camels, respectively (Table 4, Fig. 6). The study does not show areas classified as permanently not suitable even though there were factors in which permanently not suitable classes were observed.

Table 4 : Final land suitability classes for livestock with their respective areas of coverage

Suitability Classes	Livestock Species							
	Cattle		Sheep		Goats		Camels	
	Area (km^2)	Area (%)	Area (km^2	Area (%)	Area (km^2	Area (%)	Area (km^2	Area (%)
Highly suitable	218.77	5.6	192.25	4.9	211.52	5.4	396.84	10.12
Moderately suitable	1754.7	44.75	1732.01	44.17	1667.72	42.52	2298.3	58.6
Marginally suitable	1791.8	45.7	1821.29	46.45	1998.14	51	1211.02	30.9
Currently not suitable	155.73	4	175.45	4.48	43.62	1.11	14.84	0.38
Permanently not suitable	-	-	-	-	-	-	-	-
Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

IV. Discussion

Animal husbandry in rangelands has been an important economic activity in Ethiopia for a very long time. Due to land scarcity, the degree of importance attached to a specific rangeland area reflects its productivity as well as its availability for alternative sources of income. Appropriate land-use decisions are vital to achieve optimum productivity of the land and to ensure environmental sustainability. In Ethiopia, as in most other developing parts of the world, animal husbandry is the most productive means of using semi-arid zones bordering the desert. Therefore, the concept of range inventory was applied in the present instance to recognize and evaluate the actual production capabilities of rangelands for optimal utilization of these valuable natural resources for domestic livestock production.

While adapting grazing suitability analysis on rangelands, due consideration was given to land- use/ land-cover, rainfall, topography, soil, water availability, access to market, animal health services and socio-economics as the effective factors and the extent of limitations they impose are important in selecting appropriate areas within the total spread of rangelands determined rangeland suitability for the grazing of sheep and goats using a livestock grazing model considering three components, namely forage production, water resources, and the sensitivity of the soil to erosion.[15, 16, 17, 18, 19] Rangeland is in conflict with industrial development but compatible with forestry in compliance of management and control principles.[20]

Land cover is a product of human activities altering the terrestrial surface. In turn, it also governs the kind of activities that can take place over a given piece of land. A major limitation in the acceptance of rangeland in Dire District for all livestock categories is that under land-use /land-cover, a wide area fell into marginally suitable category. As against this, only a small area of the rangeland is highly suitable for livestock production because rest of the area is dominated by bush and shrubs (unpalatable for cattle and sheep) than grasses.

Slope is a very important factor determining the suitability of rangelands for livestock production. Animals can easily graze in flat and gentle slopes and most of the consumed feed goes in for fattening without much energy loss. But, places with high slope (>30%) are not suitable for livestock grazing due to their impassability and loss of energy in wandering through the steep slopes for feed and water resulting in decreased food conversion function.[21]

Rangelands characterized by the usage of different systems of grazing resources and management of communal grazing lands based on water resources offers opportunities to monitor changes in species composition and response of grasses to prolonged and intensive disturbance.[13, 22] Dire district is currently not suitable regarding water access for small ruminants (sheep and goats) and moderately suitable for cattle while highly suitable for camels. One of the intentions of the present attempt is to determine optimal creation of additional water sources to increase cattle distribution. Creation of new water sources in presently "unsuitable" areas would help in augmenting the availability of grazing areas to a large extent.

Sale of livestock and livestock products is the main source of cash income. The distance from main marketing centers influences the price of animals. Long distances and trekking to markets are major impediments for pastoral folks to profitably sell their livestock. During drought periods, animals lose weight on journey to the market, thereby losing their value significantly. In situations of surplus stock, remaining animals turn too weak to embark upon homeward journey, forcing the producers to sell them at a very low price or to go even for bartering them for food.

A comprehensive analysis of the physical settings of the Dire District rangeland revealed four major environmental variables (land-cover, rainfall, topography and soil) as most important criteria in land suitability assessment. Rainfall determines the amount of water available for plant growth. Minimal rainfall for rangeland plant growth is not so inadequate. Usually, annual rainfall of 400 mm is considered suitable. Terrain is important for maintaining slope stability and is critical to the distribution of other variables at a local scale (*e.g.,* in order to prevent soil erosion, a steep terrain should not be tilled). Soil type, slope of the area governs the type of vegetation that could grow most productively in an area, and vegetation (*e.g.,* its presence and health) indicates whether the land can be productively used or not. Usually, heavy soils with deep slope are made use for agriculture, whereas medium to coarse gravel or rubble stone soils, semi- evolved with moderate to shallow slopes remain as rangeland.[23] Further, the rangeland management system in southern pastoral areas of Ethiopia is strongly based on water management. The availability of surface water sources such as ponds and wells in order to suffice the water needs of plants and livestock together with veterinary services are essential for livestock production. The role of each of these factors in an environment varies with land-cover due to their changing dominance in different areas with different influences. Many researchers [24, 25, 26] have adopted similar methods as in the present attempt to analyze rangeland suitability through GIS techniques followed by multi-attribute decision making approach in different situations.

V. Conclusion

Assessment of rangelands is a task that frequently challenges managers in livestock industry, environmental protection and rangeland management. Rangeland suitability for livestock is a very important information for livestock development and future planning. Of the total land area in Dire District, only about 6.5 % land is found highly suitable for different livestock categories because of bush encroachment followed by poor accessibility to water resources, veterinary services and market centers. In contrast, a large extent of the rangelands is only marginally suitable for cattle, sheep and goats but moderately suitable for camels. About half of the area of the District is inaccessible to market and is devoid of major water sources or deep wells to serve the needs especially of small ruminants (sheep and goats). Acute shortage of permanent water resources for livestock especially during the dry season is a major impediment to the propagation of livestock enterprise in the region. In order to make these areas suitable on a sustainable basis, proper interventions are required to be undertaken calling for implementation of appropriate rangeland management plans in the District to encourage good livestock production for long.

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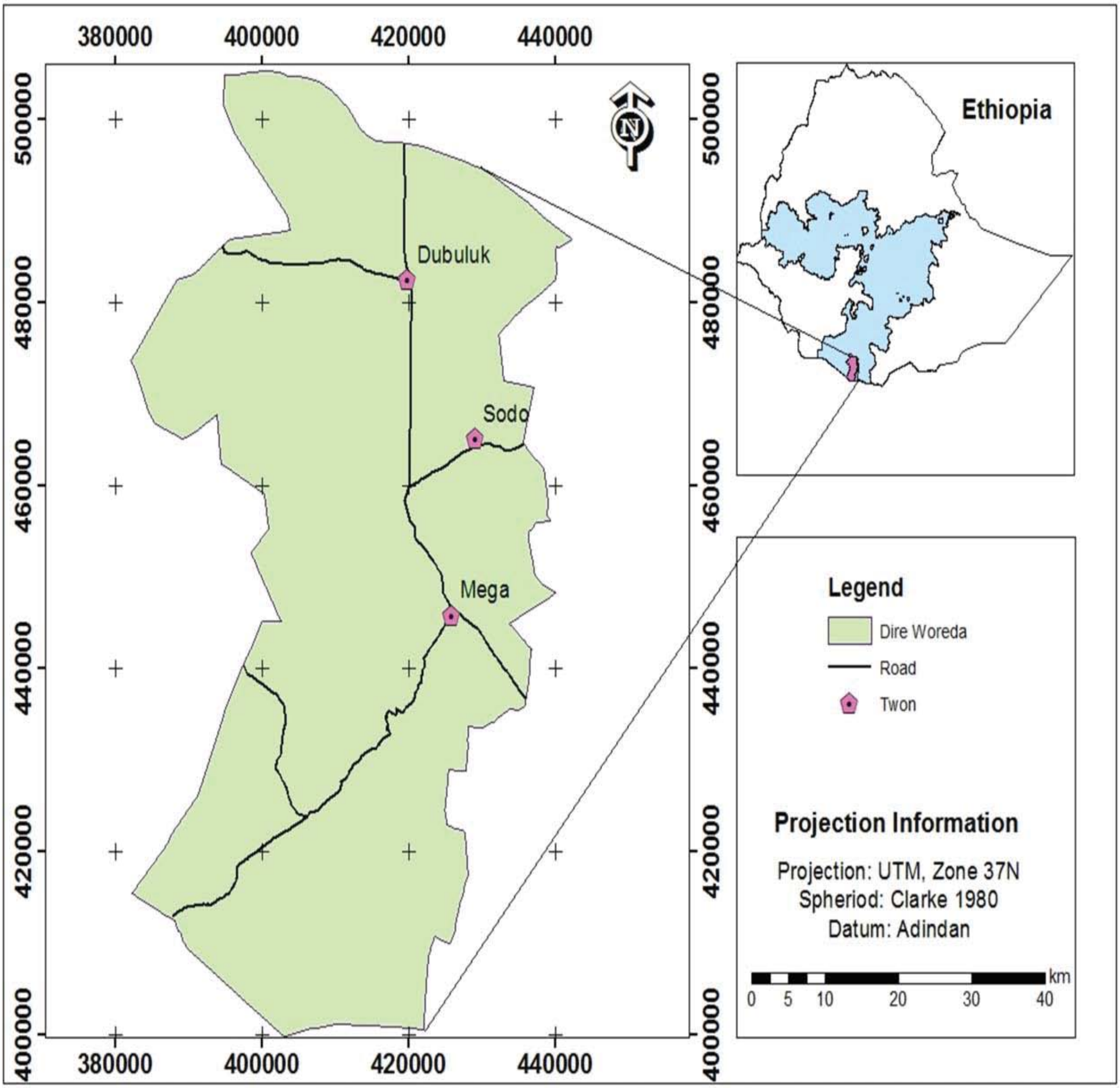

Figure 1 : Location map of the Study Area

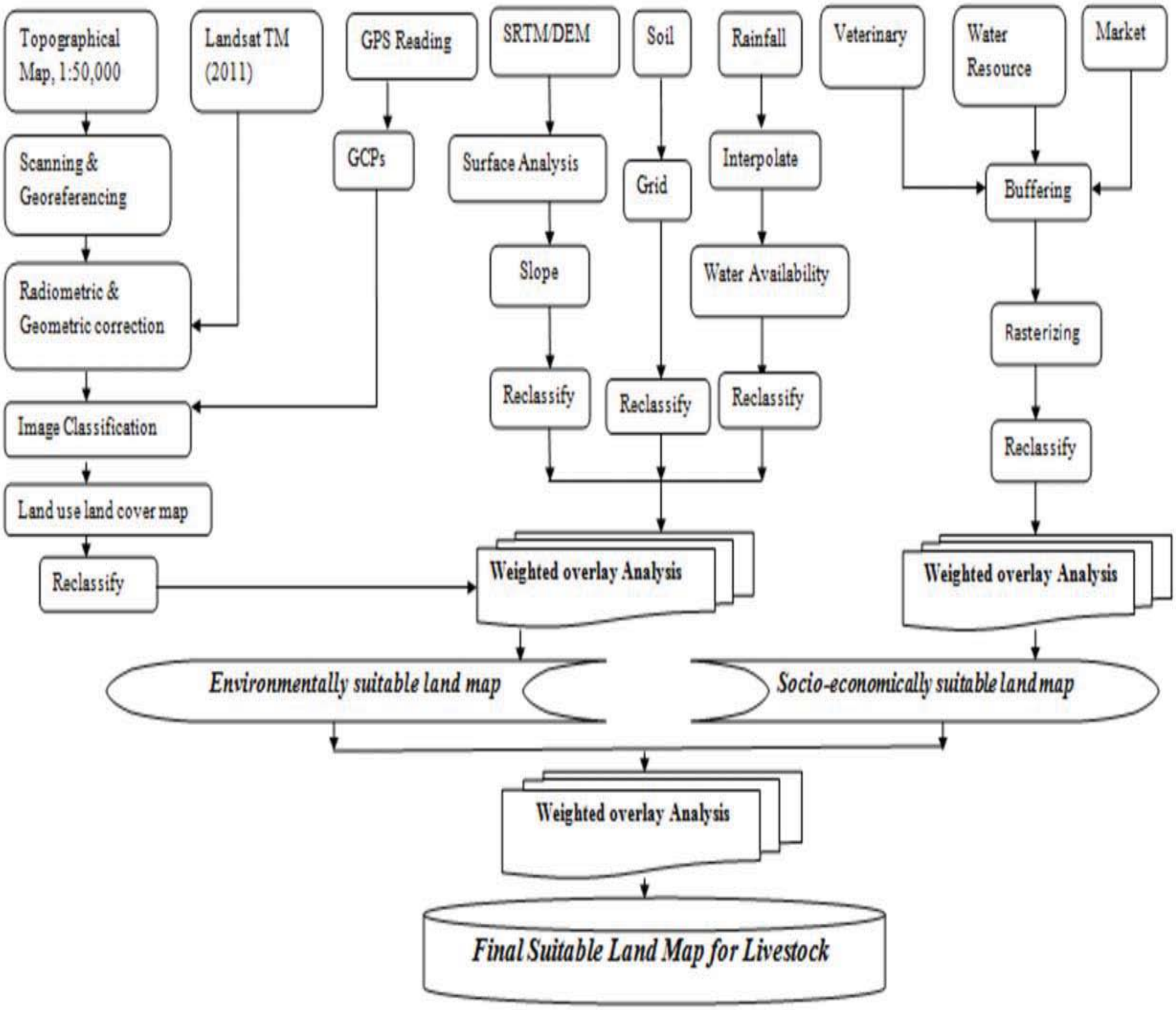

Figure 2 : Methodological flow chart

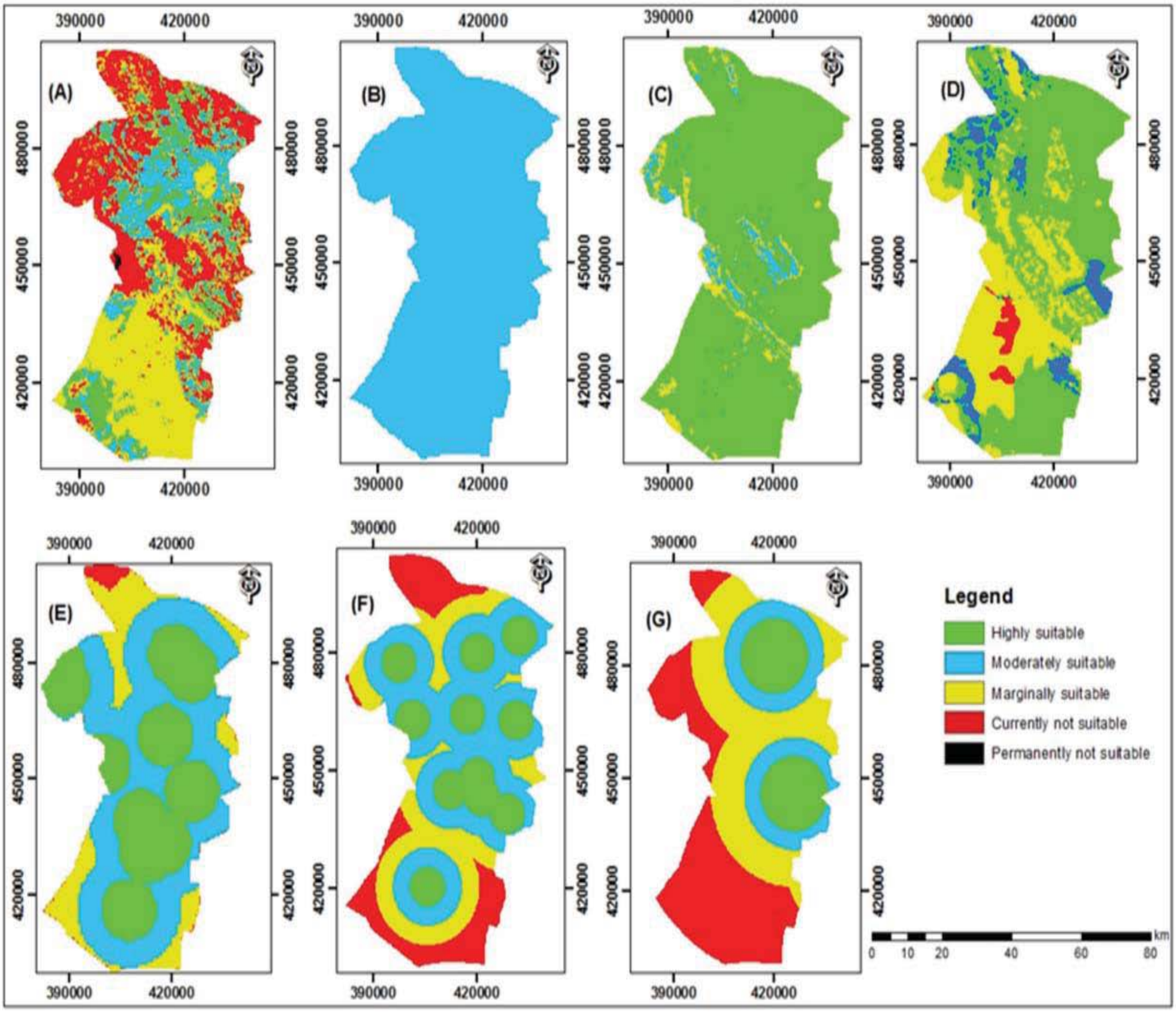

Figure 3 : Factor-wise suitability maps for Livestock
(A. Land-use/land-cover, B. Rainfall, C. Slope, D. Soil (texture), E. Water availability, F. Animal health services and G. Market access).

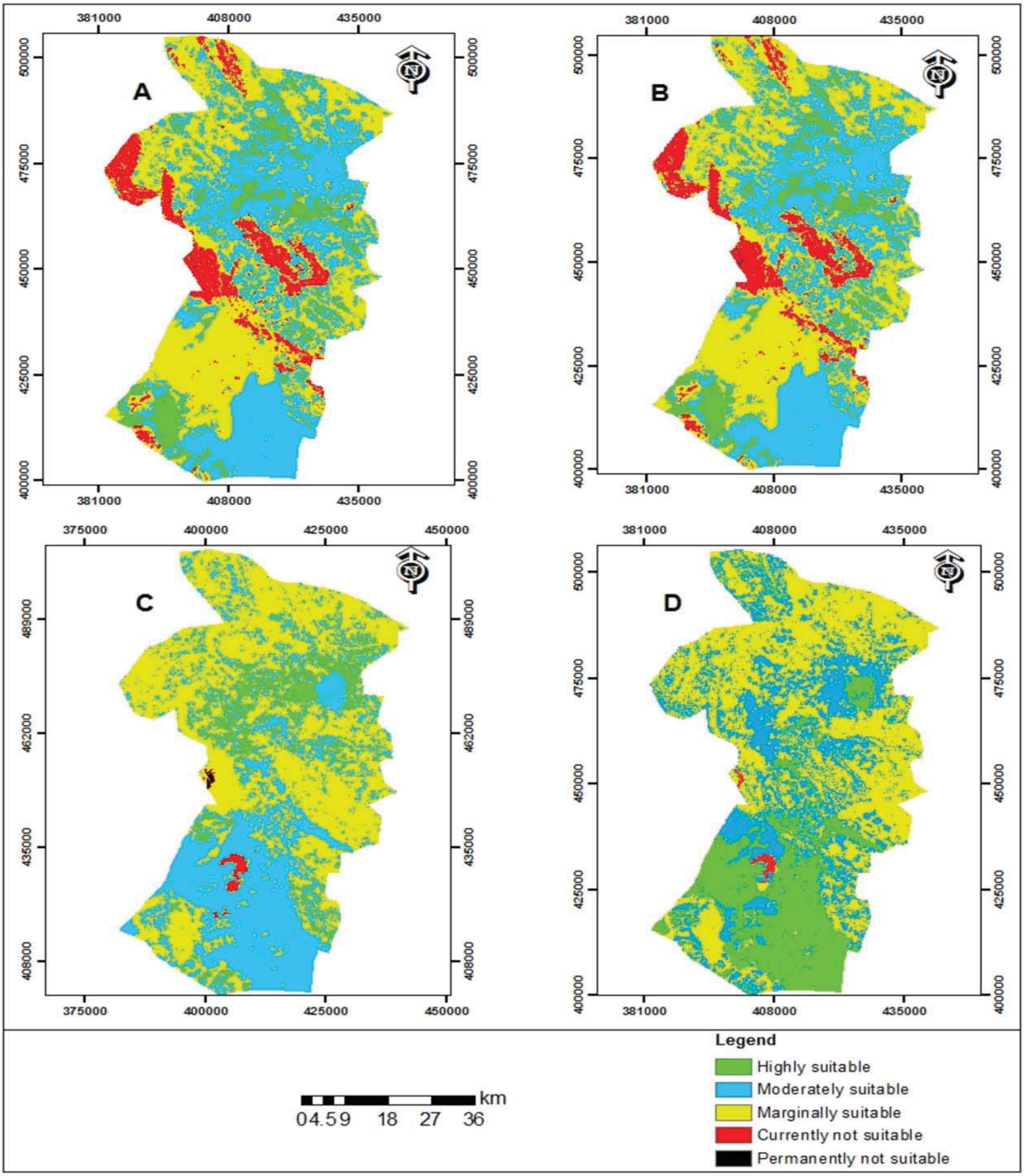

Figure 4 : Land suitability map based on Environmental parameters for A) Cattle, B) Sheep, C) Goats and D) Camels

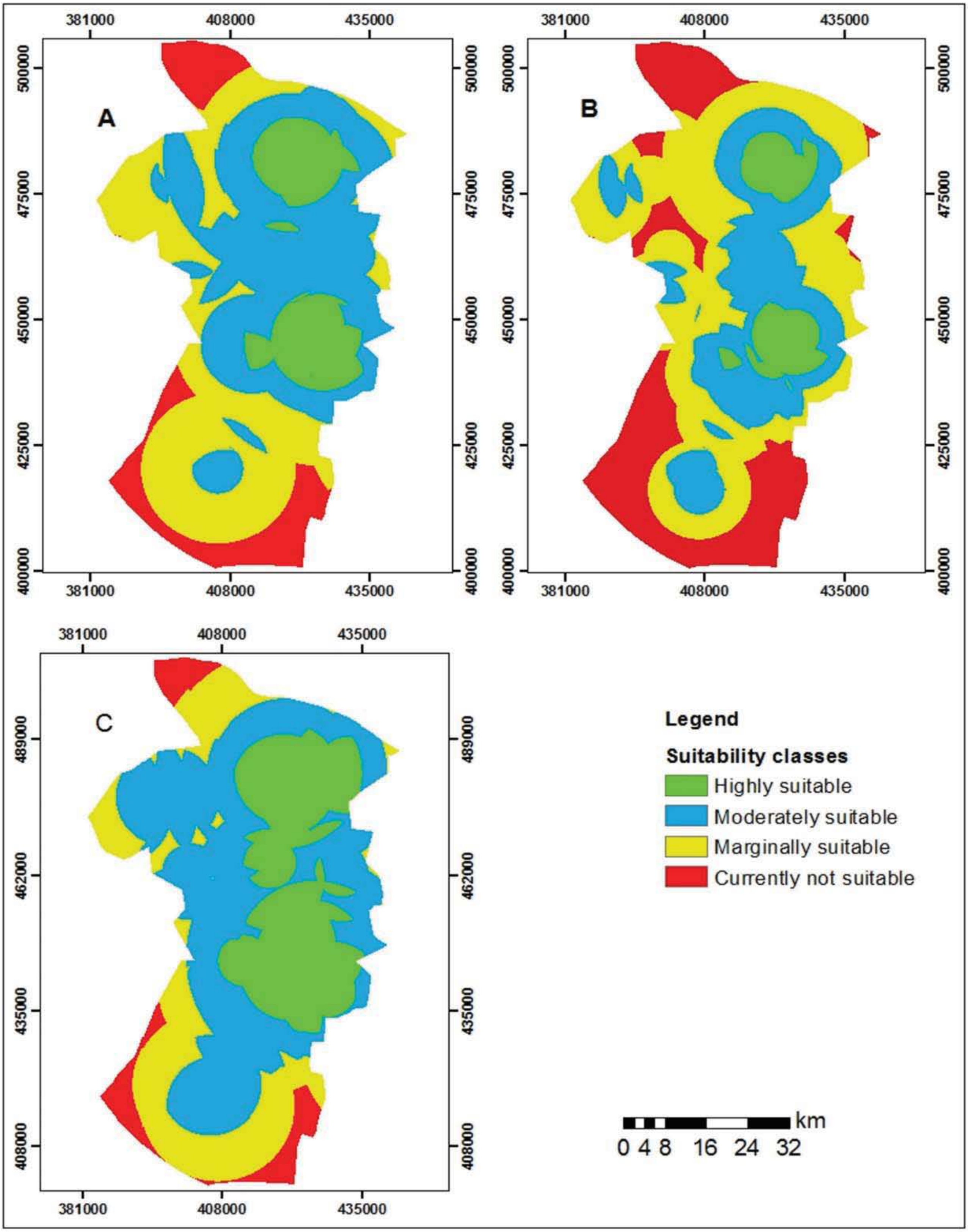

Figure 5 : Land suitability map based on Socio-economic parameters for A) Cattle, B) Sheep and Goats and C) Camels

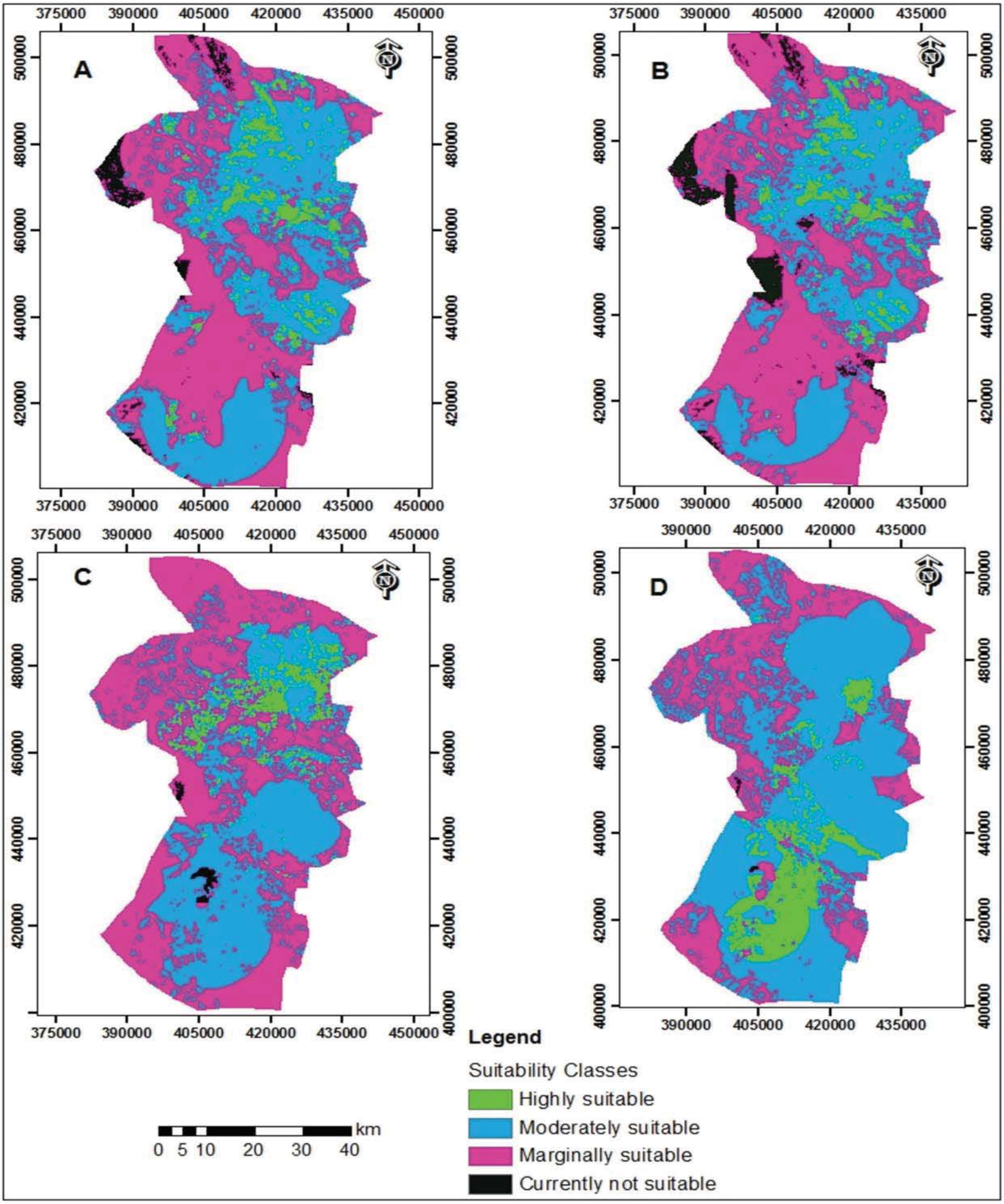

Figure 6 : Final suitability map based on both environmental and socio-economic factors for A) Cattle, B) Sheep, C) Goats and D) Camels

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The Method for Effective Co_2 Purification in the Atmosphere

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Keywords: *atmosphere, co_2, precipitation enhancement, clouds, acoustics.*

GJSFR-H Classification : *FOR Code: 059999p*

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Strictly as per the compliance and regulations of :

The Method for Effective Co_2 Purification in the Atmosphere

Svetlana Amirova [α] & Tamara Tulaikova [σ]

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Keywords: atmosphere, co_2, precipitation enhancement, clouds, acoustics.

I. Introduction

The idea of weather modification by precipitation seeding was generated earlier (Langmuir, 1937). The most popular methods used today for precipitation enhancement are the sprinkling of hygroscopic particles or a special solutions for 'warm' clouds and the introduction of glaciogenic substances into 'cold' clouds from an airplane (Mather 1997, Shmeter 2005, Drofa 2006) and etc. According to IPCC Fifth Assessment Report the predicted climate trend indicates the global overheating (Edenhofer, 2014) up to the end of century, and all known natural restore mechanisms have limited capacities in regards to the amount of incoming pollution and also they operate within specific time constants according to (Kleidon, 2010). We recall that the sum of water vapor and carbon dioxide makes a 95% of the greenhouse gases in a modern atmosphere. Mentioned aspects we used to propose new method for atmosphere purification and further climate recovery.

Our approach incorporates the possibility of stepwise CO_2 purification in two simple stages to be conducted in areas of the free atmosphere. The first stage involves spraying of alkaline compounds, such as *KOH* and etc., inside the cloud via an airplane to increase the *pH* in cloud droplets. The alkaline reagents significantly increase the solubility of co_2 in water, however rain droplets become saturated by atmospheric CO_2 during their gravitational fall. Due to the small co_2 concentration in air the probability of collision in cloud between small water droplets and co_2 molecules is low, so modified cloud droplets spend their alkali capacity later during rain. The rainy droplets provide effective transport of co_2 from the under-cloud atmospheric volumes to the ground and further more to soil, ground water and plants.

In addition to it, the special acoustic devices can be utilized to accelerate the coalescence of water droplets in modified clouds as possible second stage of proposed method according to (Tulaikova, 2010). The acoustically influencing for mists and fogs was widely used early (Boucher, 1960, Mednikov 1963) then industrial aerosols were the central purpose for the acoustical seeding, and common practice show the efficiency up to 99%. The background is the facts that acoustics provides high mobility for droplets, because they become be involving into air vibrations inside sound waves with the best coalescence as a results. The speed of acoustic-based vibrations and coalescence should be effective for cloud droplets due to high speed of acoustic waves (C ~ 340 m/sec) in comparison with typical atmosphere winds 2 – 20 m/sec. Previous acoustical experiments were only carried out near the ground earlier, but it could be most effective to place the sound generator directly inside a cloud in the region with oversaturated water steam by using a modern airplanes or helicopter.

II. The Features of Proposed Method for CO_2 Purification

The purification effect strongly correlates with changes of *pH* level in cloud water. In natural precipitation with acid or neutral *pH* the concentrations of the dissociated ions are relatively small. On the other hand, the natural ocean of our planet stores great mass of CO_2 due to alkali properties of the ocean water where is $pH \approx 8.3$. There is an established method to describe the insoluble and dissociated portions of the weak acid that remains after attaining the equilibrium of saturation for water by CO_2: $CO_2 + H_2O \Leftrightarrow H_2CO_3$, $H_2CO_3 \Leftrightarrow HCO_3^- + H^+$, and $HCO_3^- \Leftrightarrow CO_3^{2-} + H^+$. The equilibrium concentrations of dissolved and dissociated portions became $[H_2CO_3] = C_1 = 0.71$ mg/l; $[HCO_3^-] = C_2 = 3.3$ mg/l, also $[CO_3^{2-}] = C_3 = 10^{-3}$ mg/l then $pH = 7$, and given data were listed for a cloud with 3 mkg/m³

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of NH_3 (Yunge 1965, Rasool 1073). Therefore, co$_2$ solubility significantly grows at higher pH levels due to increase of H^+ concentration, and concentrations of ions [HCO_3^-] and [CO_3^{2-}] increase in 10 and 100 times accordingly by each unit of pH. The ratios of carbon in the first, second and third of the listed compounds are the following: D_1 = 0.1935; D_2 = 0.1967; and D_3 = 0.20. For given water volume U_w the carbon mass can be calculated as:

$$M_C^{Uw}(pH) \approx \left[\ 0.1935 \cdot C_1 + 0.1967 \cdot C_2(pH) + 0.2 \cdot C_3(pH)\ \right] \cdot U_w \qquad (1)$$

For instance, a precipitation layer with a height of h_w = 1000 mm covers a unit surface of 1 m^2, so the corresponding mass of carbon is equivalent to $M(10) = N_S(10)\cdot 1000 \approx 850$ g at the pH = 10. Using this approach one can estimate the concentration of CO_2 that is removed from the atmosphere underneath the cloud by precipitation. Let's take the volume of purified air in the atmosphere U_a = 10^3 m^3 in precipitation, there h_a = 1 km is the altitude of the cloud calculated from the ground for a unit square surface 1 m^2. The reduced CO_2 concentration C_{a-} could be estimated by dissolving the carbon mass in alkaline precipitation water:

$$C_{a-} \approx \frac{0.1935 \cdot C_1 + 0.1967 \cdot C_2(pH) + 0.2 \cdot C_3(pH)}{0.2727} \cdot \frac{h_w}{h_a} \qquad (2)$$

The molar mass of CO_2 is 44 g, so the share of carbon in it is D_4 = 12/44 = 0.2727. The vertical CO_2 distribution was considered here almost uniform (Machida, 2003) up 2-3 km, excluding increase in 100-200 meters near ground. For the special case of the complete atmospheric purification in the volume under cloud, we assume that the CO_2 concentration is $C_{a-} \approx$ 420 ppm. The pH level of the droplet should be increased up to pH=10.3 for complete purification if the cloud located at 1 km above the ground. In general, clouds can be located at various altitudes h_a. For instance in case of the altitude h_a = 6 km the cloud medium should become pH=10.8 to get complete purification in lower area. Let's analyze a chemical approach to introduce KOH into clouds in the form of additional liquid aerosol. There is the dissociation reaction of KOH in water:

$$KOH \rightarrow K^+ + OH^-$$

$$H^+ + OH^- \Leftrightarrow H_2O\ ,\ \ K_w = [H^+] \cdot [OH^-] \qquad (3)$$

We note that the values of water dissociation constant are taken at variable temperatures: K_w=10^{-14} at T = 20°C according to (Sillen 1964) or K_w = 10$^{-14.926}$ at T = 0°C in cloud. The required KOH mass can be obtained approximately from the relation $n_{KOH} = K_w/[H^+] = [OH^-]$ according to algorithm of (3). Taking the equality of molar concentrations for KOH and OH from relation (3) we obtain the molar concentration of alkali n_{KOH} = 10^{-4} mol/l then pH = 10, for example. The mass concentration value N_{KOH} = 56·10^{-4} g/l ≈5.6·10^{-6} g/cm^3 results from molar one by multiplication to the molar mass of KOH. Let's comment upon the data. Suppose in a cloud the liquid water content is W = 1 g/m^3, it means that air volume 1 m^3 contains the 1 cm^3 of water, and listed data of N_{KOH} corresponds required alkali mass to air volume 1 m^3 (5.6·10^{-9} kg/m^3) to get mentioned pH-level in cloud droplets after evaporation/condensation and restructuring. For example, let the cloud has a volume 1 km^3 and W = 1 g/m^3, hence the required mass of KOH to add into this cloud should be equal to 5.6·10^{-9}·10^9 ≈ 5.6 kg then pH = 10 approximately. Exact calculations for KOH mass were performed with account of condensation processes onto aerosol particles in real cloud (Tulaikova, 2012). The average KOH concentrations as a function of pH are N_{KOH} = 1.7·10^{-5} g/cm^3 then pH=10.5, and N_{KOH} = 3.5·10^{-5} g/cm^3 then pH=10.8 in comparison with N_{KOH} =5.6·10^{-6} g/cm^3 then pH=10.

We investigate a potential purification advantage of this method based or droplets assemble above the flat ocean surface. Firstly, due to small size of rain droplets the falling time exceeds the gas saturation time to provide perfect CO_2 absorption. The fall velocity $V_g(r)$ can be using the stationary speed of droplet gravitation sedimentation as follows: $V_g(r) \approx \sqrt{2rg\rho_w/\rho_a}$, where ρ_a and ρ_w are the densities for air and water respectively, r is a drop radius and g is the acceleration due to gravity. The falling time for droplet can be estimated as $t_h \approx h_a / V_g(r)$ with the initial cloud altitude of h_a = 1 km, these calculations show t_h =257 sec then r = 1 mm for example. On the other hand, we can estimate the saturation time t_{aw} for the falling droplets during the process of CO_2 solubility. The steady state concentration depends on the ratio of the air volume U_r = $3\pi r^3/3$ for the drop and the area of its surface S_r = $4\pi r^2$, and also depending on the gas exchange constant K_{aw} at the gas-water interface, the time of saturation is $t_{aw} \approx r/3K_{aw}$. The constant $K_{aw}(V)$ has been measured as a function of the velocity of air flow V over the water surface, according to (Broecher 1978, Wanninkhof 1996). We employed the following experimental measurements for constants of gas exchange at the gas-liquid interface: $K_{aw} \approx 4 \cdot 10^{-3}$ cm/s then V = 3 m/s; also $K_{aw} \approx 1.1 \cdot 10^{-2}$ cm/s if V = 7 m/s. Taking into account $K_{aw}(V)$ we obtain saturation time t_{aw} = 6 sec for droplet with a typical rain radius r = 1 mm. The largest radius in rain has been estimated as 3 mm due to drop disintegration, and at the beginning of the precipitation due to gravitational sedimentation the droplets have grown with radius $r \geq 100$ µm. For the largest droplet with radius r = 3 mm saturation time is t_{aw} = 11 sec and flying time t_h = 148 sec due to velocity

$V_g \approx 7$ m/sec. As $t_{aw} << t_h$ there is enough time for gas saturation during droplet flight to the ground from the altitude $h \geq 1$ km.

The next method's advantage is great increases of the air/water interface in droplets assemble in comparison with flat surface of ocean. Further analysis bases on the Marshall-Palmer approximation for the droplets spectrum for rain as follows $\varphi(r) = n \cdot b \cdot \exp(-br)$. This empirical formula includes the constant b (cm^{-1}), and the droplet number concentration n (cm^{-3}) that depends on the precipitation rate I, in millimeters per hour (Borovikov 1961, Kobayashi 2007). Different types of precipitations can be described by previous empirical equation for the parameters b and n using in, as follows: drizzle has $b = 57 \cdot I^{-0.21}$ with $n = 5 \cdot 10^{-3} \cdot I^{0.21}$; rains have $b = 41 \cdot I^{-0.21}$, $n = 2 \cdot 10^{-3} \cdot I^{0.21}$; and storms have $b = 30 \cdot I^{-0.21}$ with $n = 5 \cdot 10^{-4} \cdot I^{0.21}$. The radii interval for the complete rain spectrum was calculated over a wide interval $r = 0.05$ - 3 mm. The volume of received precipitation water $U_I = AIT\beta$ was calculated as a sum of all of the falling droplets, there the water layer is I on a ground surface $A = 1$ m^2 during $T = 1$ hour for all calculations as mentioned in the examples. Here rates for drizzle, rain or storm are $I = 3$; 10 or 30 mm/hour, , but the β coefficient was introduced in order to compare the features for the precipitation types, $\beta_1 = 1$, $\beta_2 = 0.3$ and $\beta_3 = 0.1$, so $I_1\beta_1 = I_2\beta_2 = I_3\beta_3$. Then the percentage of droplets with a radius r_i within the unit water volume can be described using normalized number of droplet $q_i(r_i) = \varphi_i(r_i)/\Sigma\varphi(r)$. The sub-volume of the unit volume $U_I(r_i)$ for these droplets with equal radii can be estimated as $q(r_m) \cdot U_I$, also the number of droplets in each sub-volume consist of $N_m = 3q(r_m)U_I/(4\pi r_m^3)$. The total sum for the entire droplet intervals in all volumes of sub-volumes $U_I(r_i)$ are described by the following sum:

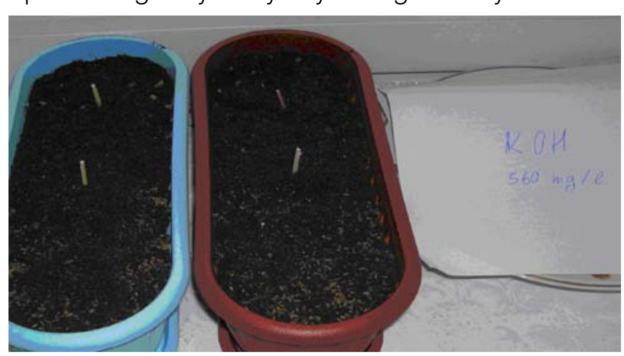
$$N = \frac{3AIT\beta}{4\pi} \sum_r \frac{q(r)}{r^3} \qquad (4)$$

Calculations according to (4) provide the total number of falling droplets in mentioned water unit. For drizzle it is $N_d \approx 6.76 \cdot 10^{11}$, for rain $N_r \approx 4 \cdot 10^{11}$, and for storm $N_s \approx 2.45 \cdot 10^{11}$ for $AIT\beta = 3$ liters of water for drizzle, rain, or storm. These results prove that rain droplets could be interpreted as a porous medium with a large surface for gas/liquid interactions as compared to the ocean's plane surface. Then, each falling droplet runs at an air cylinder with a minimal volume length h and a ground area πr_m^2. The cylinder surface $S_m \approx h 2\pi r_m$ means that air/water interface increases for rainwater and purified air contact. The total sum of this surface for all droplets in considered water unit is, as follows:

$$S \approx \sum_r N_{m,I} S_m = \frac{3AIT\beta h}{2} \sum_r \frac{q(r)}{r^2} \qquad (5)$$

provide the following numeric values: $S_d \approx 3 \cdot 10^8$ m^2 for drizzle, $S_r \approx 2 \cdot 10^8$ m^2 for rain, and $S_s \approx 10^8$ m^2 for storm. The corresponding calculations for expanded atmospheric air/water interface considering droplet set were done in precipitation volume $S_{hA} = 4 \cdot 10^3$ m^2 with altitude $h_a = 1$ km and ground surface $A = 1$ m^2 for precipitation time $T = 1$ hour. As a result, the formula (5) demonstrates the 10^5 times increase in air/water surfaces for purification possibilities as a result of rain. Due to their linear contribution in formulas for N and S, the values of T, h, I, and A can be multiplied by any numeral for real time, altitude, rain intensity or grand square. Due to the small co_2 concentration in cloud media the probability of collision between water droplets and co_2 molecules is low; but erosion of co_2 as well as a significant decrease in its concentration occurs in the sub-cloud precipitation volume.

An extra advantage of proposed approach is very positive plant response to the precipitation resulted from proposed method. To emulate the process of co_2 absorption in water droplets during an indoor experiment, the similar changes were made in alkaline solution during long-time diffusion according to formula $L_{lab} \approx (D \cdot t)^{1/2}$, diffusion coefficient is D =$\cdot 10^{-5}$ cm^2/sec, but L_{lab} there is a water layer depth. The KOH was dissolved in water and resulting mixture was kept indoors during several hours $t = L^2_{lab}/D$, as a result the solution has ions of $K+$; HCO_3^- ; CO_3^{2-}. The initial $pH = 12$ was kept in these experiments. After 9-hours of saturation time t, the plants in brown pot were given the resulting solution, but the same volume of pure water was added to control blue pot (left side) with the same plants, Fig.1(a-d). These two watering processes were repeated regularly every day during January 2014.



a

b

c

d

Figure 1 : The indoor plants after 0 (a), 19 (b) and 30 (c) days correspondingly; (d) is the next plants after 19 days in the same soils with the same watering procedures. The plants in a right (brown) flower pot were watered by solution with ions CO_3^{2}; HCO_3^- ; K+.

The experimental plants are beetroots (10 grains), carrots (20 grains), and much number of parsley (2 Grams) in each of plant pots, see Fig.1 (a, b, c).The second experiment was done later with the same soil after deleting previous plants; the next portion ware planted, there are 20 grains of dill and 5 grains of cucumber for each plant pot. The same watering process was repeated regularly every day during February 2014, results are presented at Fig.1d. One can see a strong vegetation growth by enriched solution watering according to proposed method for all studied plants.

III. The Method Consideration

In general the proposed method can be applied for the whole Earth on the global scale. The surface area of our planet is $A_E \approx 5{,}1 \cdot 10^8$ km^2 and the average annual layer of precipitation is $h_w \approx 1{,}000$ mm. Using equation (1) one can estimate the mass of removed atmospheric carbon (M_C^1) in 1 meter of precipitation water measured per surface 1 m^2 at $pH = 10 - 10.8$, for details see 1st and 2nd rows of Table. The carbon ratio in CO_2 is 0.2727, hence the amount of carbon oxide is $M_{C02}^1 = M_C^1/$ 0.2727 and its value listed at the 3th row of the Table. Note, the $M_{C02}^1 = 5.9 \cdot\cdot 10^{-4}$ then pH=5.6 for typical rain. The calculated mass of formed carbon at the surface A_E of the whole planet is $M_C^A = M_C^1 \cdot A_E = 0.849 \cdot 5.1 \cdot 10^{14}$ $\approx 4.3 \cdot 10^{14}$ kg then $pH = 10$, as listed at the 4th row of the Table. The CO_2 value $M_{CO2}^A = M_{CO2}^1 \cdot A_E = 3.11 \cdot 5.1 \cdot 10^{14} \approx$ $1.6 \cdot 10^{15}$ kg listed at the 5th row of the Table. In 2010 the global CO_2 emission reached an amount of $3.06 \cdot 10^{13}$ kg. For further calculations let's assume the global annual emission of CO_2 as the value $AE = 3.2 \cdot 10^{13}$ kg, for example. To compensate an annual CO_2 emission from the ratio AE / M^A_{C02} we estimate the minimal area at the Earth's surface (A_p, %) to be used for proposed technology and the corresponding details are given at the 6th row of the Table. For our approach the proposed method could to be applied on 2% - 0.14% of planet surface to compensate the annual carbon emission. To sum up let's estimate the mass of alkali to add for desired modifications in clouds. The mass *KOH* (Q_{KOH}) can be estimated using previous data for n_{KOH} from (3). Considering the precipitation layer of 1 m/year for the planet surface *A* its necessary percent *(%A)* can be estimated from the Table. The added mass of alkali at $pH = 10$ level is calculated here:

$$Q_{KOH}^{10} = n_{KOH} \cdot 1 \cdot A \cdot (A_p) \approx 5.6 \cdot 10^{-3} \cdot 1 \cdot 5.1 \cdot 10^{14} \cdot 0.02 \approx$$

$$5.7 \cdot 10^{10} \text{ kg} = 57 \text{ mil.Tons} \qquad (6)$$

Note that similar estimations are presented at the bottom row of the Table. In comparison with the fertilizers for soil the added mass of alkali is relatively small. A required modification of the clouds can be achieved with the help of aircraft by spraying alkaline aerosol particles on top of the clouds and also by lifting of alkaline gas from the ground (Tulaikova 2012).

Table 1 : The carbon mass ($M^A{}_C$) and CO_2 mass ($M^A{}_{CO_2}$) for the Earth's surface $A_E = 5.1 \cdot 10^8$ km^2; the minimal required surface (A_p) and mass of KOH (Q) to compensate an annual carbon emission

1) pH-level	10	10.5	10.8
2) M_C^1 per 1m^3, kg	0.849	4.05	12.06
3) M_{CO2}^1per 1m^3, kg	3.11	14.8	44.2
4) $M^A{}_C$, mil. Tons	$4.3 \cdot\cdot 10^5$	$2.1 \cdot\cdot 10^6$	$6.2 \cdot\cdot 10^6$
5)$M^A{}_{CO_2}$, mil.Tons	$1.6 \cdot\cdot 10^6$	$7.7 \cdot\cdot 10^6$	$2.3 \cdot\cdot 10^7$
6) A_p , %	2%	0.42%	0.14%
7) Q_{KOH} ·, mil. Tons	57	38	25

IV. Acoustical Impact Inside Cloud for Droplet's Coalescence

The most interesting perspective for today is a joint utilization of two methods at the same time, which means that hygroscopic particles and acoustic influence would be directly applied inside one cloud area. Dynamics of different hygroscopic particles show that only first 15 ÷ 20 seconds demonstrate very fast changes in the main cloud characteristics as the supersaturation and spectrum dispersion. This is accompanied by an increase of the radii inside small drops from 0.01 ÷ 0.1 μm up to 1 ÷ 3 μm. So, after the first major variations of these parameters they increase with the same tendencies very slowly, so significant changes in spectrum of cloud and precipitation increase up to time 30 – 50 minutes (Drofa, 2006). It could be understood as initiation of water vapor condensation onto surface of hygroscopic particle from surrounding, but next stage will be the evaporation from the host cloud droplets with further condensation to new particle, such reorganization need much time. The idea is that drops could be triggered by sound waves in the form of vibrations to provide the coalescence to a drop size of more than 100 μm, and after this point gravity will predominate.

The propagation, absorption and attenuation of sound in clouds decrease with distance *(x)* in ideal air media, as follows:

$$P = P_0 \exp(-\alpha x),$$

$$\alpha = \frac{b \cdot \omega^2}{2\rho \cdot C_a^3},$$

$$b = \frac{4}{3}\eta + \frac{\gamma - 1}{C_p} \cdot a_T + \eta' \approx 2.5 \cdot \eta \qquad (7)$$

The absorption coefficient α of sound in the medium is expressed in m^{-1}. There ω is a sound circular frequency in air, η is the dynamic viscosity, the C_p heat capacity at constant pressure and the ratio of specific heat capacities is γ, the α_T is a thermal conductivity (m^{-1}). Theory predicts the absorption maximum in the range of few tens of Hz. Attenuation β may be expressed in sec^{-1}, then the value of α (m^{-1}) must be multiplied by the speed of sound. Measurements in the water mist then water liquid content is W = 2 g/m^3 for the more interesting frequency range for further consideration are: β = 3.5 dB/s for f = 58 Hz; β = 2.8 dB/s for f = 112 Hz; β = 3.6 dB/s for f = 150 Hz; β = 6.7 dB/s for f = 200 Hz (Mednikov, 1965). Measurements and calculations indicate further sound attenuation is not high α ~ 10^{-3} ÷ 10^{-2} dB/m in dry air, then the sound frequency is f = 3 ÷ 10 *kHz*. As the humidity increases up to 12 ÷ 20 % , the attenuation increases up to 0.17 ÷ 0.56 *dB/m*. For higher frequencies the attenuation does not depend strongly on the humidity and give the values: α = 0.15 ÷ 0.05 m^{-1} then f = 20 *kHz;* and etc. Using mentioned measured data we deduce that at low frequency (f = 50 - 200 Hz) the acoustical wave can propagate ~ 500 meters in typical clouds prior to decreasing in energy by a factor of 2. The x = 0.5 km is enough distance in cloud for initiation of the reorganization for precipitation to begin. In practice, the most effective glaciogenic particles run the distance of ~0.1 km in cloud from airplane prior to their evaporation or sublimation, such distance provides enough cloud reorganization for precipitation enhancement. The effects of the partial dissipation of irradiated sound waves during their propagation in a turbulence medium have been measured and considered in (Corner 1958, Ostashev 1992), for example. Clouds with plenty or prolonged rainfall are identified as *Ns, As, Cb* and *Cu*, they are more important for the utilization of proposed methods. Autumn and spring clouds are mixed with water droplets, ice crystals and snowflakes. The authors of paper (Connolly 2005, Connolly 2006) studied the formation and shapes of cloud fractions using both experiments and theories, they gave convenient empirical formula that can be employed in order to determine the percentage of water vapor, liquid, and solid phases in real clouds created by the adiabatic process.

The purposes of further analyses is to calculate an amplitude, *L(r,ω),* during the vibrations for typical droplet sizes inside acoustic wave to find no high optimal power. The optimal regimes below were analyzed and calculated for the ensemble of cloud droplets: the optimal frequency (f) should be low enough with an appropriate decrease in the acoustical power, *Q*. The power decrease tends to weight and size minimization these are desirable from a real utilization in helicopter. Typical clouds have droplet radii within the range from $r \approx$ 1 - 50 μm, and the objective for the acoustics is the additional motion of the droplet ensemble in receiving greater droplets with radii $r \geq$ 100 μm. Known model (8-9) was developed earlier for small droplet assembles (Fuchs 1064), it gave good description for special media like smoke or industrial fogs where radii r ≤ 1 μm are small. The Stokes friction for air flow at the droplet's surface provided particle's motion inside acoustic wave, which is physical core of this model. For more large cloud droplets this model wrong, because it predicts the equality for the velocities of air V_a and droplet V_w for small frequencies ω, see the first term in right side of result equation (9). The acoustic pressure is $P(t) = P_a \cdot sin(\omega t)$, ω is the circular frequency of the acoustic wave This model present equations with their solutions, as follows:

$$m\frac{dV_w}{dt} = 6\pi\eta r(V_a - V_w) \qquad (8)$$

$$\tau\frac{dV_w}{dt} + V_w = V_{a,\max}\sin(\omega t)$$

$$V_w = \frac{V_{a,\max}\sin(\omega t - \varphi)}{\sqrt{1+\omega^2\tau^2}} + \frac{\omega\tau V_a}{1+\omega^2\tau^2}\cdot\exp\left(-\frac{t}{\tau}\right) \qquad (9)$$

There relaxation time is $\tau \approx 0.22 \cdot \rho_w \cdot r^2/\eta$, τ ~ 10^{-7}s for particles radius 0.1 μm, but τ ~ 10^{-5} s for r = 1 μm, it provides zero in the second term in right side of (9) for low frequency then t ~ π/ ω. As a result, the medium/droplet delay $\varphi = arctan(\omega\tau)$ is small here when $\tau\omega << 1$. This model was developed for small particles then $r << 1$ μm was the norm, but frequency was in *kHz* range. Therefore, using this model we found that the velocity amplitude of driving cloud droplets becomes equal to the speed of the air molecules $V_w \approx V_a$ in (9). Of cause, this is an incorrect model for large-sized droplets in clouds which need much driving force for their big masses.

The new model is suggested here for large droplets inside clouds. Air molecules bombard great droplet surface at ½ front side to pass their impulse for droplet motion, the result is the creation of the driving force. It provide droplet vibrations back and forth in the acoustic wave; moves the droplets with an amplitude *L* that has a maximal displacement during a time for half the period, as follows:

$$L_{\max} = \int_0^{\pi/\omega} V(t)dt \qquad (10)$$

there *L* is the droplet amplitude, but *V(t)* is its velocity. The modern complete model of one-dimensional vibration for a cloud droplet in a viscous medium can be found, for example, in (Prokhorov 1997, Kumazaki 1999), as follows:

$$\left(\frac{4\pi r^3}{3}\rho_w + f_2\right)y'' + (f_0 + f_1)y' = F\cdot\sin(\omega t) \quad (11)$$

$$f_1 = 6\pi\eta_a r + 3\pi r^2\sqrt{2\eta_a\rho_a\omega} \qquad (12)$$

$$f_2 = 3\pi r^2\sqrt{2\eta_a\rho_a/\omega} + \frac{2}{3}\pi\rho_a r^3 \qquad (13)$$

where are water and air density are ρ_w, and ρ_a; η_a is medium viscosity, and *F* is a driving force amplitude. The coefficients f_1 and f_2 correspond to the medium counteraction and are proportional to the speed and acceleration, respectively; f_0 corresponds to the inner mechanical losses that are, in reality, small. One can see that the Stokes's term, the first term of f_1 (12) is introduced into the motion equation (11). However, the second term in (12) provides the drag. The second part of f_2 characterizes the vibration of the joint mass of the medium surrounding a droplet, the first term in (13) corresponds to acoustic radiation losses. The solution of mentioned system (11-13) for the droplet velocity $V(t) = y'$ provides the following equation:

$$V = C\cdot\exp(-2ht) + \frac{B}{(2h)^2+\omega^2}\left[2h\cdot\sin(\omega t) - \omega\cdot\cos(\omega t)\right] \qquad (14)$$

where normalized acted force is $B \approx F\backslash m \approx F\backslash(1.333\pi r^3\rho_w)$. The attenuation parameter is *h* which follows from the initial equation *V=0* then *t=0;* also the integration-resulted term *c* is as follows:

$$h = \frac{f_0 + f_1}{f_2 + 4\pi r^3\rho_w/3}, \qquad C = \frac{B\omega}{\left[\omega^2 + (2h)^2\right]} \qquad (15)$$

The droplet amplitude for half of the period of acoustic waves is *L*, the final solutions are as follows:

$$L = \frac{B}{\omega^2 + (2h)^2}\left\{2\frac{2h}{\omega} - \frac{\omega}{2h}\left[\exp\left(-\frac{2h\pi}{\omega}\right) - 1\right]\right\} \qquad (16)$$

The driving force, *F,* should be determined at this point in order to obtain the numerical calculations, and it is necessary to set the predominant mechanism for the counteraction of acoustics using the weighted droplet in air to add the vibration. Here we assume the bombardment of the front surface of the large droplet by small air molecules; as well as the impulse transfer required to move the droplet to another location. The simplest formula of such a physical model describes the impulse transfer, $F\cdot\Delta t = \Delta p$. Side surface effects can be neglected for large droplet objects according to the next chapter consideration. The affecting force increases in proportion to the area of the front surface is ~ $2r^2$. However, the droplet mass grows with radius as ~ r^3 that is mass driving is predominate. Molecule forward or back motions occur during the time of half period of the wave $t_{1/2} = \pi/\omega = 0.5f^{-1}$. The volume of air molecules in the front of the droplet is $U_N = S\cdot\int_0^{\pi/\omega} V_a(t)dt = \pi r^2 V_a 2/\omega$, but the cross-section of water droplet is $S = \pi r^2$. The complete mass for air molecules in this volume is $M_a \approx N\cdot 28\cdot m_p\cdot U_N$. Here Avogadro's constant, and taking molecular mass for nitrogen is $2\cdot 14 m_p$. We put to use for estimations the average molecule's velocity in acoustical wave $V_a/2$. Driving force in acoustic wave according to second Newton's law could be found $F = M_a\cdot\Delta V/\Delta t \sim M_a\cdot V_a/t_{1/2}$, and it corresponds to the next equation:

$$F \approx (28 m_p N)\cdot r^2 V_a^2 = C_F\cdot r^2 V_a^2 \qquad (17)$$

where the coefficient is $C_F \approx 1$ in the SI system. The acoustic pressure, *P,* in the sound wave; the acoustic power, Q; the velocity, V_a, of the air molecules; their displacement, L_m; and the speed of sound C_a are connected as follows:

$$V_a = \sqrt{\frac{2Q}{\rho_a C_a}}, \quad P_a = \rho_a C_a V_a, \quad L_m = \frac{1}{2\pi f}\sqrt{\frac{2Q}{\rho_a C_a}} \qquad (18)$$

Below we introduce the pulse power *J,* then $Q = J\cdot f$. After previous unification, the driving force or large droplets in the acoustic wave is as follows:

$$F \approx \left(\frac{2C_F}{\rho_a C_a}\right) r^2 J \cdot f\,, \quad B=F/m_w \qquad (19)$$

The droplet mass is $m_w=4\pi r_w^3/3$, the droplet give the amplitude $L(f,r)$ in the from $L(f,r)$:

$$L(f,r)=\frac{Jf}{r}\cdot\frac{C_{F2}}{(2h)^2+(2\pi f)^2}\cdot\left\{\frac{2h}{\pi f}+\frac{\pi f}{h}\cdot\left[1-\exp\left(\frac{-h}{f}\right)\right]\right\} \qquad (20)$$

There coefficient is $C_{F2}=\dfrac{3C_F}{2\pi\rho_w C_a\rho_a}$.

Numerical calculations and the results are presented in Figure 2 according to proposed model (10-20). Figure 2 demonstrates examples for some optimized regimes for three acoustical ranges, as follows: (1) f = 20 Hz with lowest power Q = 175 W/m^2; (2) f = 50 Hz with Q = 800 W/m^2 and (3) f = 100 Hz with Q = 2500 W/m^2. Additional analysis were performed using the introduction of appropriate altitude changes relative to the main physical parameters in the model, as follows: air density (ρ_a), viscosity (η), sound velocity (C_a), and air temperature depending on km-altitudes. A decrease in necessary acoustic power using the 2 – 6 km location of cloud with sound source within the atmosphere was observed, so calculations indicated a 10-15% increases for the amplitude values, L, according to the acoustics applied to the cloud drops directly at a altitudes of 6 km above the ground. For a typical cloud droplet, the estimations indicate that gravity is negligible small (0.1%), as well as the drag force, due to the friction of air flow at the surface of the droplet.

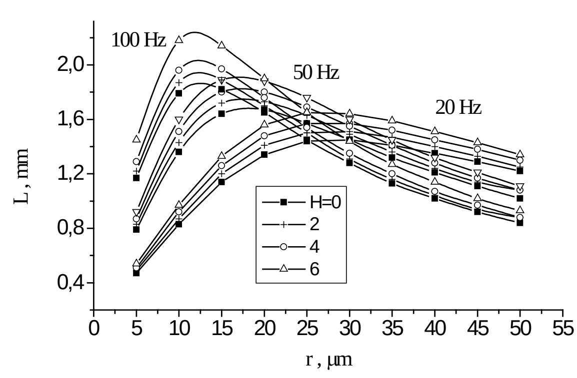


Figure 2 : Vibration amplitudes L for droplets radii 5 – 50 μm for their location at altitudes H = 0, 2, 4, 6 km. The regimes are: f = 100 Hz and Q =2.5 kW/m^2; f = 50 Hz and Q =800 W/m^2; f = 20 Hz and Q = 175 W/m^2

Now let's estimate the optimal average distance that should allow the droplets to collide. An average number concentration of droplets in a cloud occurs in the range from N ~ 60 – 1000 cm^{-3} and more according to various measurements, see for example (Borovikov, 1961). Here we assume that N ~ 500 cm^{-3} specifies the individual volume occupied by a weighted drop 1/N, and that its average distance is L_i ~ $N^{1/3}$ ≈ 1.26 mm. The proposed regimes at Figure 2 provide necessary amplitudes for the typical ensemble of cloud droplets. The time requirement is L_i / r ≈ 1260/10 = 2 minutes or more to provide coalescence probability. The probability of the complete or partial amalgamation for two collision rainy droplets depends both on their sizes and velocities as listed below. The irradiation time should be more longer for low frequency affects.

V. The Acoustic Technique to Facilitate Precipitations

Sirens are believed to be most suitable generators for powerful sound in air medium (Hartman 1939, Gladishev 2000). The variant of siren is composed of a fixed stator with small holes in the periphery, and it has a stator located inside of the rotating rotor with the same numbers of holes. The holes of the rotor and stator periodically overlap, so the compressed air comes out from siren core from time to time. Outgoing air kicks to the walls of the resonator vibrating on own resonance frequency to put acoustical signal to the outer media. The siren frequency is given by the number of holes (or teethes) z, and the number of rotor circulation per second, n_c, as follows $f = zn_c$. For example, when n_c = 12.5 c^{-1} and z = 8, the frequency is f = 100 Hz; or the n_c = 6.25 c^{-1} then frequency is f = 50 Hz. This frequency is related to the rotor speed and the fundamental mode of the resonator to maximize power output for the signal. The siren was constructed and tested in experiments, so the frequency change of the rotation speed is done by coupling the motor and the transformer with the variable voltage in order to tune speed for experiments.

Let's describe below the features of Bessel-form resonator to get pure monochromatic wave by high spectrum selection into fundamental mode of resonator. The idea is that the shape of the optimal resonator for a siren should have Bessel-formed walls to maximize the power of acoustic radiation to a fundamental harmonic within output beam. The fundamental harmonic distribution for energy in the radial direction is $J_0(kr)$ of propagated fundamental wave. The sound frequency is f, and sound speed C_v = 340 m/s, for wavelength (Λ), when f = 100 Hz we have: $\Lambda = C_v/f = 3.4$ m, the wave vector $k_0 = 2\pi/\Lambda = 2\pi f/C_v$. The first zero-solutions for the Bessel function is $x_0=2.404826$ for $J_0(k_0r_0) = J_0(x_0) = 0$, such that the reflector's output radius, r_0, meters, can be modified to the formula $k_0r_0 = x_0 = 2.404826$, and as follows:

$$r_0(f)=\frac{x_0}{2\pi\cdot f}\cdot C_v \approx \frac{130}{f} \qquad (21)$$

The calculated data for the outlet radiuses of Bessel's resonators are: $f = 100$ Hz needs $r_0 = 1.3$ m; $f = 50$ Hz needs $r_0 = 2.6$ m and etc.

At the outlet of proposed reflector (at $x_0 = 2.4$), the edges should be folded outwards as a bell-shape to avoid edge diffraction with appropriate transfer of the radiated power into the higher harmonics. Technically, such a reflector could be manufactured using long and narrow strips of sheet of metal; strips could be assembled according to the principle of the fan and held together by transverse belts. The output siren powers can be estimated using data at Fig.2. These data should be multiplied to the output resonator square $S_{res} = \pi r_0^2$ then resonator output radius r_0 was calculated from equation (21), as follows:

$$Q_0 = 2.5 \cdot S_{res} \approx 13 \text{ kW then } f = 100 \text{ Hz};$$

$$Q_0 = 0.8 \cdot S_{res} \approx 21 \text{ kW then } f = 50 \text{ H} \qquad (22)$$

There are sirens with similar output power, and manufactured siren in (Tulaikova 2010) had power up to $Q_0 \approx 4$ kW. The experimental tests in mist areas demonstrate the coagulation effect, but the siren power should be increased by the factor 3 for $f = 100$ Hz according to (22). The simple way to do it is the increase of the number of holes by factor 3 or the same increase of hole's surface, so radiuses should be increased up to $1.7 \cdot r$. The air output flow near siren holes is $V \approx 300$ m/s and summarized holes surface $S_0 = 3$ cm^2. Calculation show that the siren needs the air pump about ~ 0.1 m^3/s. Let's consider ways of improving of acoustical effect and/or acoustic technique. To begin with we note, that the siren will be more effective then the average number N_{cl} of droplets in a cloud is higher then considered here number $N = 500$ cm^{-3}, so let's assume $N_{cl} \sim 1000$. The average droplet distances will be $L_m \sim 1$ mm and according to previous estimation: $L_m \sim N^{-1/3} \approx 1$ mm. The vibration amplitude from equation (20) is linearly proportional to the acoustic power necessity J. This means that such cloud has small output acoustic power from siren according to (22) and Fig.2: $Q_0/2 \approx 6.5$ kW.

Also considered here is the type of moved siren with air inside pumped by the strong oncoming of the air flow through additional cylinder with compression system (Karnovsky 1945). Such device can be located at airplane and oriented according to its axis, so incoming air flow is captured by compressed system to put air to sired rotated core, and also to the Bessel-resonator through summarized holes surface S_0. The axis of Bessel-form resonator should be oriented at opposite to moving direction. The model and calculation show high efficiency to get air pumping inside moved siren cylinder then airplane velocity is not supersonic.

The following acoustic action utilizes a helicopter. Small airplane is typically used in clouds for precipitation enhancement and so hygroscopic particles distributed into the cloud from an airplane. Note that a helicopter can serve this purpose much better, because it is less speedy and more maneuverable then an airplane. The helicopter has the following advantage in comparison to the airplane. The rotor blade of the helicopter rotates with a sufficiently large angular velocity, so the linear velocity at the end of each blade reaches the speed of sound. Typical helicopters blade has a length of 10 meters and its partial speed varies linearly from 0 to 300 m/sec, but suppose helicopter is moving forward with some speed, for example 100 km/h = 360 m/sec then supersonic motion of one blade is produced in small time periods. This effect takes place because there are the same directions of helicopter motion and one of its blades moving in the same direction with its own speed. It means that each of the blades overcomes the supersonic regimes producing the shock wave. The shock wave has a steep front and big difference of pressure and temperature comparable to surroundings. So such wave pushes the droplets to coalesce effective and also provides a rapid condensation. Fast condensation inside the shock wave can be seen in many photographs when airplane breaks the sound barrier.

VI. Conclusion

In this paper two staged approach for free atmosphere CO_2 purification is proposed. To begin with alkaline reagents were injected into natural clouds in order to increase their pH-level up to 10 or 11. Enhanced precipitation facilitated for the carbon transport from atmosphere to the ground. It was shown by corresponding calculations that there is a considerable increase of the gas/water interface for CO_2 absorption; and grass photos indicates the positive plant's reaction to water at initial $pH = 12$. Note that the proposed acoustic method is up to date and does not require extensive support. The models and calculations are presented for the regimes of acoustic power that are required to implement inside cloud according to proposed new low-frequency model. Acoustic method provides fast droplets coalescence inside nature clouds and sedimentation "to get rain at the right time". Additionally, artificial rains facilitate air purification and climate corrections. The resulting effect can compensate for annual carbon emission by applying method at 0.4 % – 0.1 % of the Earth surface.

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Spatial Assessment of the Recorded Incidents of Mud on the Road in Herefordshire

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Abstract- The deposition of mud on the road has serious consequences including contributing to serious and fatal accidents. The objective of this paper was to assess the correlation between reported occurrences of mud on the road in Herefordshire and spatial and temporal factors that may have contributed to the risk of mud ending up on the public highway. Relevant datasets including incidence data (mud on road) from Herefordshire County Council, land use, soil data, erosion risk, slope and data through Digi map online, were combined and spatially analyzed using a GIS (Geographical Information System) software. The results indicated that the highest numbers of mud incidents occurred between October 2013 to April 2014 and 83% of these cases occurred in areas with high erosion risk. The land use data showed that 42% of Herefordshire was arable. Soil data showed that over 74% of the soil texture was silt clay loam which is suitable for arable farming. The data also showed that as rainfall increased mud incidents increased.

Keywords: *land use; mud incidents; rainfall; soil texture; slope, erosion.*

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SPATIALASSESSMENTOFTHERECORDEDINCIDENTSOFMUDONTHEROADINHEREFORDSHIRE

Strictly as per the compliance and regulations of :

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Abstract- The deposition of mud on the road has serious consequences including contributing to serious and fatal accidents. The objective of this paper was to assess the correlation between reported occurrences of mud on the road in Herefordshire and spatial and temporal factors that may have contributed to the risk of mud ending up on the public highway. Relevant datasets including incidence data (mud on road) from Herefordshire County Council, land use, soil data, erosion risk, slope and data through Digi map online, were combined and spatially analyzed using a GIS (Geographical Information System) software. The results indicated that the highest numbers of mud incidents occurred between October 2013 to April 2014 and 83% of these cases occurred in areas with high erosion risk. The land use data showed that 42% of Herefordshire was arable. Soil data showed that over 74% of the soil texture was silt clay loam which is suitable for arable farming. The data also showed that as rainfall increased mud incidents increased. It could be inferred that the major driving factors of mud incidents in Herefordshire are land use, soil type and rainfall.

Keywords: land use; mud incidents; rainfall; soil texture; slope, erosion.

I. Introduction

The intentional or unintentional deposition of mud on the road is an offence in the UK (Highways Act, 1980). As well as being illegal, deposition of mud on the public highway has serious consequences including serious and fatal accidents. In rural areas most incidents are often apportioned to farming operations primarily, accessing land to harvest a crop in less than favorable conditions, and subsequently driving the vehicle on a public highway (Cornwall Council, 2014). Soil properties vary naturally across the landscape (Campbell, 1979). Spatial variability in soil properties particularly soil texture may, therefore, account for spatial variability of occurrence of mud on the road because, for example, of their variability in stickiness (as affected by clay content) and also because of the associated crops grown in a particular soil type.

Mud on the road is believed to be caused by heavier vehicles such as tractors, trailers and Lorries, the risk of this is increased following significant rainfall (Cornwall Council, 2014). Mud on Herefordshire roads is believed to be putting lives at risk by causing dangerous situations (West Mercia Police, 2012). Farmers were warned not to leave mud on the roads after three accidents in Herefordshire, when the West Mercia Police had no option than to close three A roads (BBC England, 2012). Mud on the road was also blamed for a crash that killed a mother and son near Leominster in February 14, 2012 (Hereford Times, 2012). Various factors are expected to have a major influence on the incidents of mud on road. These ranges from; land use, crop type, the design of the road, slope of the area, and the vehicle tire/track design.

Mud can occur as a suspension of solids concentration. Muds can be homogenous, as in the case of a well-mixed suspension or a rapidly emplaced bed, or exhibit strong vertical gradients in mechanical properties due to self-weight consolidation (Dade et al., 1992). Soil is at sticky point when it is just wet enough to cling to a foreign material across its surface (Fountaine, 1954).

The adhesion force is mainly due to the water film at the contact surface between the soil and the material (Wang et *al.,* 1998). According to Gill and Berger (1967) the water films thickness is determined by soil properties, moisture content and the roughness of the material's surface. Since vehicle tyres are design for higher adhesion to the soil to reduces the tendency of slipping or skidding, adhesion of mud to tyres is very likely to happen which increases the risk of mud being transported from a field.

II. Materials and Methods

a) Geographical Location of Herefordshire

Herefordshire is an English county in West Midlands, with a land area of 2,180 sq. km, located at Latitude 52.08 and Longitude -2.75. Herefordshire is one of the most rural and sparsely populated counties in England, with a population density of 82 km^2. The M50 road runs through the south of the county. The hilly nature of the terrain in mid Wales means that the ground transport links between North Wales and south Wales run through Herefordshire. The other trunk roads in Herefordshire are the A49 and A465, which form part of these north-south routes across the county as well as catering for local traffic.

b) Soil

The underlying geology of Herefordshire is predominantly Old Red Sandstone, which is relatively

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permeable material therefore leading to well-drained soil ideally suitable for agriculture. The soil series comprises well drained reddish brown or brown very fine and fine sandy loams and loams overlying fine grained Devonian sandstone rock (Mathew, 2009). The parent material is of variable colour but mainly reddish brown, fine grained micaceous sandstone which is sometimes thinly inter bedded with siltstones or marls and may be slightly calcareous.

c) Land Use

The study area is predominantly arable land. In recent times arable land has led to an increase in erosion and over a third of the arable land in the UK is likely to erode (Robinson and Blackman, 1989). Large farms are found mainly on the wide, flat floodplain and terraces of the Wye Valley and on the sandy soils of the southernmost parishes of Herefordshire.

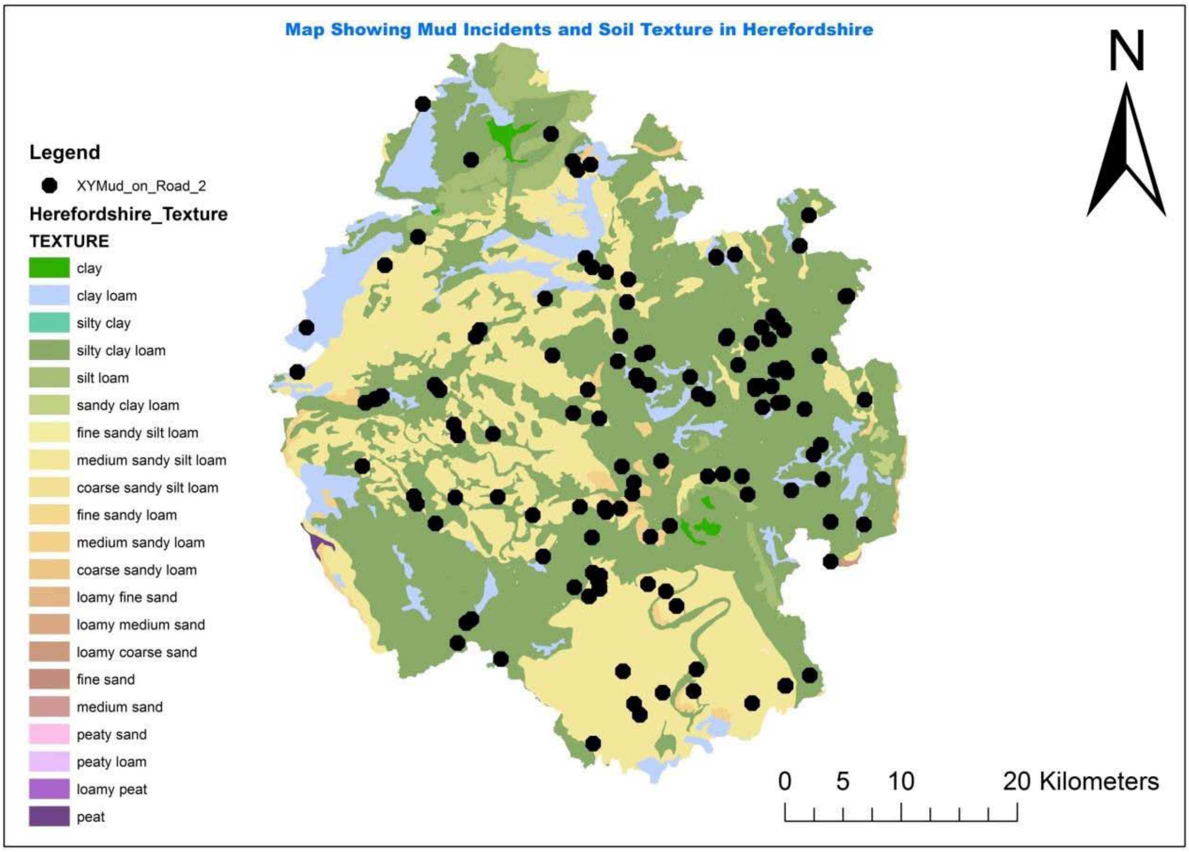

Figure1 : Mudincident sand soil texturein Herefordshire

Figure 2 is a map showing mud incidents in relation to soil texture in Herefordshire. The incidents were dominant in areas with silty clay loam. This could be because it also covers the greatest land area of 74%.

d) Data Analysis

In order to achieve the set objective, relevant datasets were collated including incidents data (mud on road) from Herefordshire County Council, land use, soil data, erosion risk, slope and data through Digi map online. The above data was spatially analysed using GIS (Geographical Information System) software, and ArcMap version 10.2. The mud incidence data was spatially joined to other data sets to evaluate the corresponding factors contributing to the mud on road incidents. The data was graphically plotted using Microsoft Excel 2007 in order to identify the major factors contributing to mud on the road in Herefordshire. The recorded locations of mud incidents were also viewed using Google Earth in order to assess terrain features.

III. Results and Discussion

Analysis of mud on road incidents recorded by Herefordshire Council between September 2013 and June 2014 shows that mud incidents occurred mostly during October-December, and least during May and September (Figure 3). The result may be due to accessing the farm for various operations during the autumn, winter and early spring. The low occurrence of incidents in September may be due to incidents not being reported.

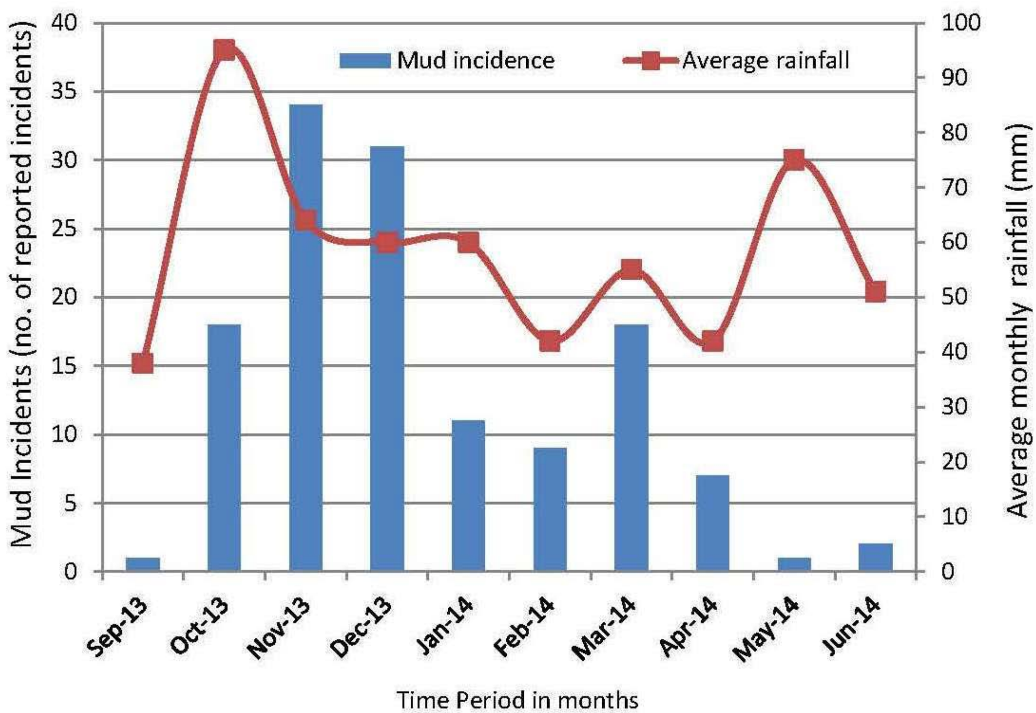

Figure 2 : Bar chart of Mud on road incidents with reference to months of the year they occur (total number of incidents=132) and monthly rainfall (mm).

The analyzed spatial data suggests that the reported incidents of mud on road (Figure 2) were highest from October-December and lowest in May. These incidents of mud on road were reported to have been caused by farmers harvesting potatoes (West Mercia Police, 2012). This period (October - December) coincided with intensive arable farming operations (harvesting of potatoes, harvesting of sugar beet, plowing, and transporting of feeds for livestock).

Figure 3 and Table 1 shows the frequency of mud on road with respect to land use (RPA dataset 2010) in Herefordshire and the references codes. Most of the mud incidents occur in areas were crops such as wheat, barley, maize and annual fruits and vegetable crops were cultivated. High incidents of mud on road in arable land may be due to accessing the land for various operations including late harvesting of potatoes and maize and drilling of winter wheat, oilseed rape and barley.

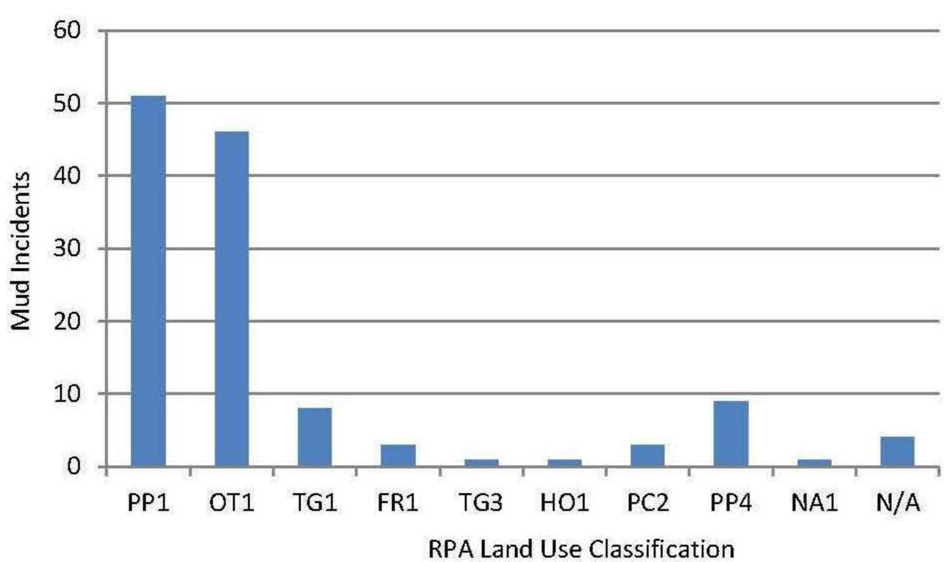

Figure 3 : Relationship between mud incidents and land use (see Table 2 for land use codes) (RPA dataset 2010)

Table 1 : RPAlanduse (2010)code and their code references

Land use code	Code references
PP1	Permanent pasture land including grazed woodland
OT1	Field use for crops such as wheat, barley, maize, and annual fruits and vegetables crops
TG1	Temporary grassland field
FR1	Forest/woodland area
TG3	Temporary grass land field area
HO1	Field used for planting Hops
PC2	Permanent fruits and vegetable field
PP4	Permanent pastureland
NA1	Land in non-agricultural activities for more than 28days
N/A	Not available

Establishing relationships between parameters such as vegetation cover, rainfall, runoff and soil loss is challenging (Zokaib and Naser, 2012). The rainfall was highest in summer but the frequency of reported mud incidents was higher during the autumn, winter, and early spring. According to Robinson and Blackman (1989) there is a higher tendency of erosion in areas of arable cultivation during autumn, winter and early spring. Monthly runoff and soil losses are expected to be higher from summer to autumn due to high amount and intensity of rainfall.

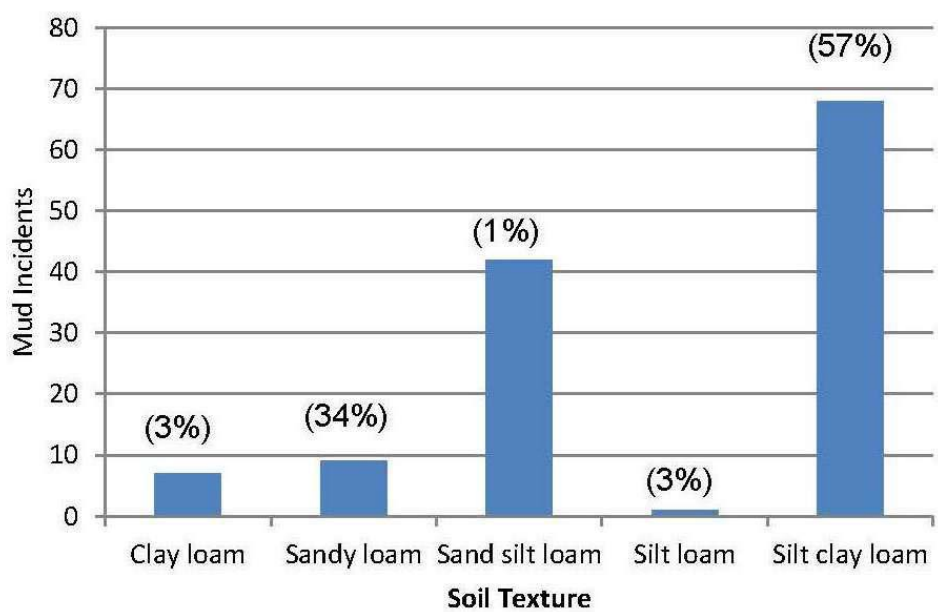

Figure 4 : Relationship between mud on road incidents and soil texture (percentage area of soil texture in catchment shown in brackets).

From Figure 4 it can be seen that the highest occurrence of mud incidents (n=68) occurred in silt clay loam textured soils. The second highest occurrence of mud incidents (n=42) occurred in sandy silt loam soils. Silt loam soils had the least value of mud incidents. This suggests that mud incidents has had a greater occurrence in areas with silt clay loam type soil texture.

Figure 5 shows the relationship between frequency of mud on road and the slope of the terrain in a range of classified slope (°). The slope was classified for easy interpretations as the mud incidents occur across a wide range of slope. Mud incidents are seen to be highest in areas that are relatively flat, which is between 0° to 9°. There may be several reasons for this. From the plot the trend of relationship between mud incidents and slope gradient of the terrain tends not to follow the same trend. There seems to be a negative relationship between slope and mud incidents.

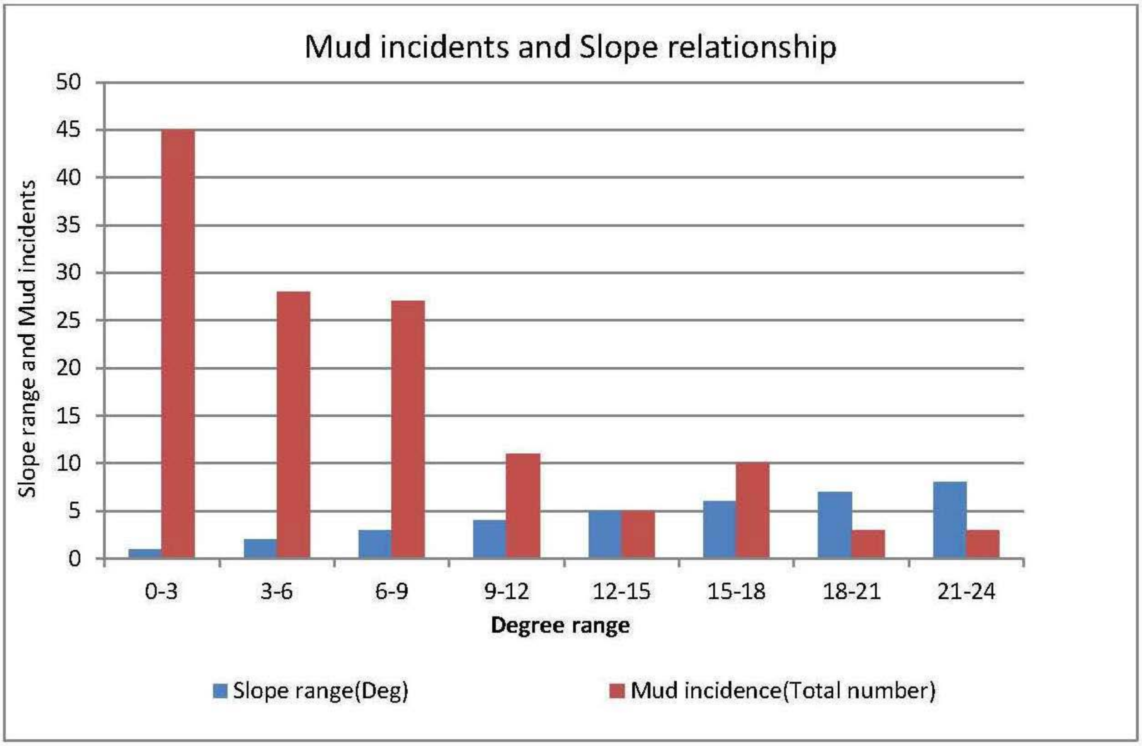

Figure 5 : Relationship between mud incidents and slope

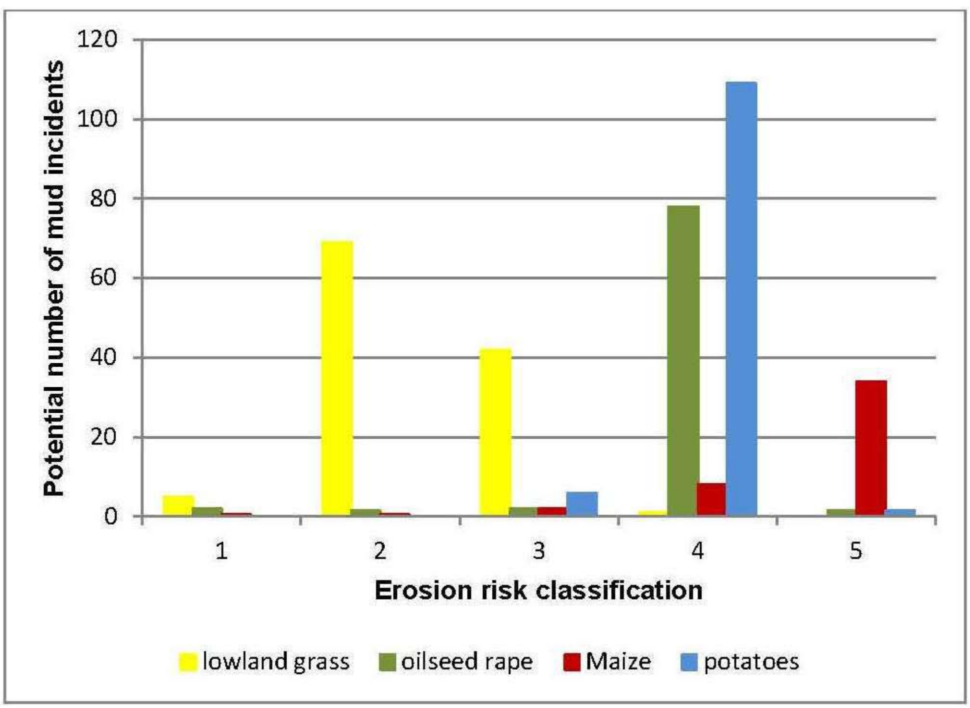

Figure 6 : Mud incidents and Erosion Risk Relationship: X axis represents Erosion risk classification (see table 3)

Mud incidents and erosion risk relationship is shown in Figure 6 using the reclassified values as shown in table 2. The layer data output was reclassified due to some unusual negative and very high values of the output data layer of erosion risk obtained for Herefordshire. The figure shows the erosion risk with the following crops e.g. potatoes, maize, oilseed rape and low land grass in relation to the reported mud incidents in Herefordshire. Assuming that the following crops were planted in the locality of the reported mud incidents, approximately 83 % of the mud incidents occurred in areas of high erosion risk for potatoes and 78% for oil seed rape. Twenty six percent of the mud incidents occurred in areas of very high erosion risk for maize, while approximately 32 % of the mud incidents occurred in areas of low erosion risk for lowland grass. The high incidents of reported mud on road in areas of high erosion risk with crops such as potatoes may be due to late harvesting between September and October when the soil was wet and therefore more adhesive to vehicle wheels (Pickersgill, 2001).

Table 2 : Reclassified range of erosion risk data.

Erosion risk (t ha^{-1})	Reclassified values (t ha^{-1})
<0.5	1-very low risk
0.5-1.0	2-low risk
1.0-2.0	3-moderate risk
2.0-5.0	4-high risk
>5.0	5-very high risk

Table 2 shows the reclassified values of erosion risk. Less than 0.5 is classified as (1-very low risk) between 0.5 to 1.0 is classified as (2-low risk), 1.0 to 2.0 classified as (3- moderate risk) between 2.0 to 5.0 classified as (4- high risk) and greater than 5.0 classified as (5- very high risk).

IV. Conclusion

The results of the slope and texture of the area shows suitability of the area for arable farming, it is important that the resources are not over utilized and therefore degraded in order to prevent incidents of mud ending up on the road.

Incidents of mud on the road have become an environmental menace in Herefordshire. It is important to identify which kind of land uses will be more suitable to address the issue of mud ending up on road in terms of crops combinations, this research should be site specific. Well-designed land uses, based on scientific information, will be crucial in reducing mud on the road by reducing soil erosion or sediment build up which could be transport to the road by vehicle movement. Site specific research will be required in the future in this regard. It is only suspected at the moment that the current land use (arable) which dominates the area is a primary contributing factor to mud ending up on the roads in Herefordshire.

V. Recommendations

The following measures are recommended:

1. Improving the aggregate stability of the soil.
2. Increasing the infiltration capacity of the soil to reduce runoff
3. Ensure the soil surface is cover to protect the soil from raindrop impact
4. Planting of buffer strip to reduce runoff from field
5. Changing the gate position if the field slopes towards the gate.
6. Consider land use change
7. Better enforcement of the 2005 single payment scheme.
8. Culverts, gulley's and drains needs regular monitoring and maintenance by all relevant stakeholders (i.e. farmers, council authorities, landowners, the police and the environmental Agencies).
9. The farming calendar should be cross check with monthly pattern of erosivity in the area to see how well the soil is protected from degrading.

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Relations between Sea Surface Roughness, Wind Speed at 10m, and Wave Parameters during a Tropical Cyclone

By Professor S. A. Hsu
Louisiana State University, United States

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I. Introduction

In the atmospheric boundary layer under hurricane conditions at sea, the logarithmic wind profile is valid (Hsu, 2003) so such

$$U10 = (U^*/k)Ln\,(10/Zo) \quad (1)$$

According to Taylor and Yelland (2001),

$$Zo/Hs = 1200^*\,(Hs/Lp)\ \hat{}\ 4.5 \quad (2)$$

$$Lp = (g/2\pi)\ Tp\ \hat{}\,2 = 1.56\ Tp\,\hat{}\,2 \quad (3)$$

Where U10 is the wind speed at 10m, U* is the friction velocity, k (=0.4) is the von Karman constant, Zo is the aerodynamic roughness length, Hs is the significant wave height, Lp is the dominant wave length, g (=9.8 m/s ^ 2) is the gravitational acceleration, and Tp is the dominant wave period.

In air-sea interaction studies, particularly the wind-wave interaction for engineering applications such as estimation of design winds and waves,on-site measurements ofU10, Hs, and Tp are needed but are not normally available. It is therefore the purpose of this research to find relations amongst these parameters so that if one of these parameters is known, one may use these relations to estimate the other.

II. Methods and Data Analysis

Simultaneous measurements of wind and wave parameters are available during Hurricane Kate in November 1985. The dataset is provided in Table 1. In order to investigate the wind-wave interaction, the effects of swell need to be minimized. According to Drennan et al (2005), the criterion to do so is to set that

$$Hs/Lp \geq 0.020 \quad (4)$$

Wherethe parameter, Hs/Lp, is called wave steepness.

Table 1 indicates that the maximum U10 was 47.3m/s (with gust to 58.5m/s) and Hs was 10.7m at 17UTC on November 20 in 1985 at the National Data Buoy Center (NDBC) Buoy 42003 in the Gulf of Mexico.

Table 1 : Measurements of wind and wave parameters at Buoy 42003 during Kate In November 1985 (Data source: www.ndbc.noaa.gov), see text for explanation

Day	Hour, UTC	U10, m/s	Gust, m/s	Hs, m	Tp, sec	Hs/Lp
18	0	8.1	8.9	1.2	5.9	0.022
18	2	8.2	8.9	1.1	5.9	0.020
18	5	7.7	8.4	1.1	5.9	0.020
18	7	7.7	8.4	1.1	5.9	0.020
18	16	8.9	9.9	1.5	6.3	0.024
18	17	9.2	10.4	1.5	6.3	0.024
18	18	9.5	10.4	1.5	6.3	0.024
18	19	8.9	10.4	1.6	6.3	0.026
18	20	8.7	9.4	1.6	6.7	0.023

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18	21	9.6	10.4	1.6	7.1	0.020
18	22	9.7	10.4	1.6	7.1	0.020
18	23	9.8	10.4	1.7	7.1	0.022
19	0	10.2	11.5	1.7	6.7	0.024
19	1	8.8	9.9	1.6	6.7	0.023
19	2	9.2	9.9	1.5	6.7	0.021
19	3	9.4	10.4	1.5	6.7	0.021
19	4	9.8	11	1.5	6.7	0.021
19	5	9.2	10.4	1.5	6.3	0.024
19	6	9.2	11	1.4	6.7	0.020
19	7	11.7	13.1	1.5	6.3	0.024
19	8	10.7	12.5	1.6	5.6	0.033
19	9	11	13.1	1.8	5.9	0.033
19	10	10.4	11.5	1.6	6.7	0.023
19	11	11.4	12.5	1.9	6.3	0.031
19	12	9.9	11.5	1.9	6.7	0.027
19	13	9.4	10.4	2	7.1	0.025
19	14	10.3	11	2.1	7.7	0.023
19	15	11	13.6	2.2	7.1	0.028
19	16	10.8	12.5	2	7.1	0.025
19	17	11.2	13.1	2	7.7	0.022
19	18	12	13.6	2	7.7	0.022
19	19	12.5	14.1	2	7.7	0.022
19	20	13.2	15.7	2	7.7	0.022
19	21	13.6	15.2	2	7.1	0.025
19	22	13.3	15.7	2.4	7.1	0.031
19	23	13.6	15.2	2.3	7.1	0.029
20	0	12	14.1	2.4	7.7	0.026
20	1	10.8	12.5	2.3	7.7	0.025
20	2	12	14.1	2.4	7.7	0.026
20	3	13.4	15.7	2.6	7.7	0.028
20	4	14.3	16.2	2.6	7.7	0.028
20	5	16.9	19.9	2.7	7.7	0.029
20	6	16.2	18.8	3.1	7.7	0.034
20	7	16.6	21.9	3.7	8.3	0.034
20	8	20	24	4.6	11.1	0.024
20	9	21.6	26.7	5.5	11.1	0.029
20	10	24.1	29.3	5.4	11.1	0.028
20	12	23.1	27.2	7.4	14.3	0.023
20	13	23.6	28.7	7.5	12.5	0.031
20	14	26	31.9	7.2	12.5	0.030
20	15	29.3	37.1	8.6	14.3	0.027
20	16	35.9	43.4	9.4	12.5	0.039
20	17	47.3	58.5	10.7	12.5	0.044
20	19	36.5	47.6	7.1	11.1	0.037
20	20	35.5	47.6	6.6	9.1	0.051
20	21	29.9	37.6	6	10	0.038

20	22	23	27.7	5.6	8.3	0.052
20	23	22.2	26.7	5.3	9.1	0.041
21	0	20.9	26.7	4.8	9.1	0.037
21	1	20.8	24.6	4.5	10	0.029
21	2	21.5	26.1	4.4	9.1	0.034
21	3	20.4	24.6	4.3	10	0.028
21	4	22.2	26.7	3.8	7.7	0.041
21	5	22.7	27.2	5.1	9.1	0.039
21	6	19.2	22.5	5.2	9.1	0.040
21	7	16.7	19.9	4.5	9.1	0.035
21	8	16.1	18.8	4.5	10	0.029
21	9	15.2	18.3	4.3	10	0.028
21	10	14.6	16.7	4.3	10	0.028
21	11	15	19.3	3.9	9.1	0.030
21	12	14	17.2	3.7	9.1	0.029
21	13	13.4	15.7	3.9	9.1	0.030
21	14	13.9	16.7	4.6	10	0.029
21	15	13.8	15.7	3.8	9.1	0.029
21	16	12.3	14.1	4.1	10	0.026
21	17	13.4	15.2	3.9	9.1	0.030
21	18	12.2	14.6	4.1	10	0.026
21	19	11.2	14.6	3.7	10	0.024
21	20	10.2	12	3.6	10	0.023
21	21	10.4	12.5	3.4	9.1	0.026
21	22	10.6	12	3.4	8.3	0.032
21	23	9.4	12.5	3.3	10	0.021

Based on the dataset as listed in Table 1, a relation between Hs and Tp is found and presented in Fig.1, which is

$$Tp = 5.56\ Hs\ ^{\wedge}0.37 \quad (5)$$

So that, from Eq.(3),

$$(Hs/Lp)\ ^{\wedge}\ 4.5 = (Hs/\ (1.56*Tp\ ^{\wedge}\ 2))\ ^{\wedge}\ 4.5 = 2.66*10^{\wedge}(-8)\ Hs^{\wedge}1.2 \quad (6)$$

Now, substituting Eq. (6) into Eq. (2), we get

$$Zo = 3.2*10\ ^{\wedge}\ (-5)*Hs\ ^{\wedge}2.2 \quad (7)$$

Therefore,

$$10/Zo = (10/(3.2*10\ ^{\wedge}\ (-5)))*\ Hs\ ^{\wedge}\ (-2.2) \quad (8)$$

Hence

$$Ln(10/Zo) = 12.7 - 2.2\ Ln\ (Hs) \quad (9)$$

Eq. (9) is also shown in Fig. 2.

Similar results for Typhoon Man-Yi are presented in Figs.3 and 4 based on the dataset provided in Table 2.

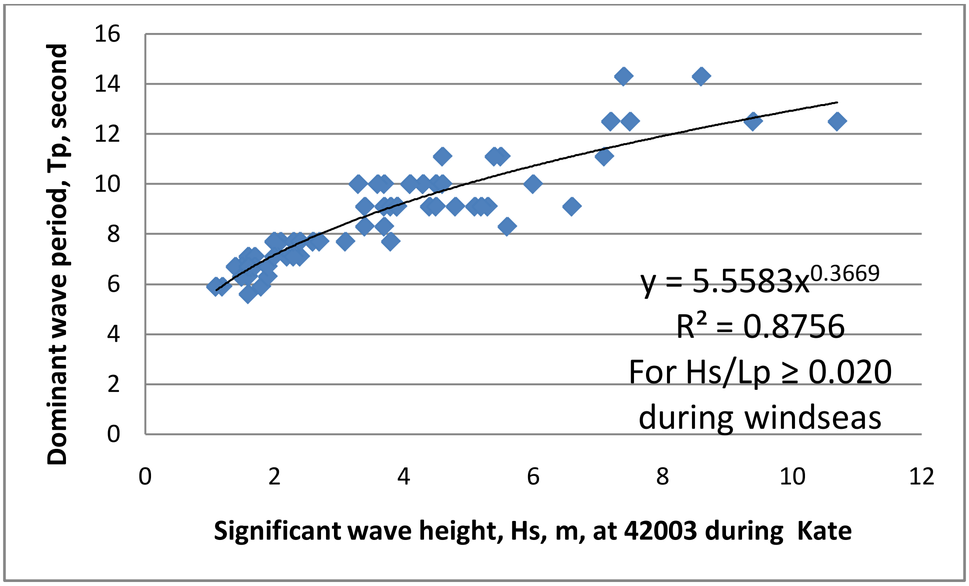

Figure 1 : A relation between significant wave height, Hs, and dominant wave period, Tp, at NDBC Buoy 42003 during Hurricane Kate in November 1985 (see Table 1)

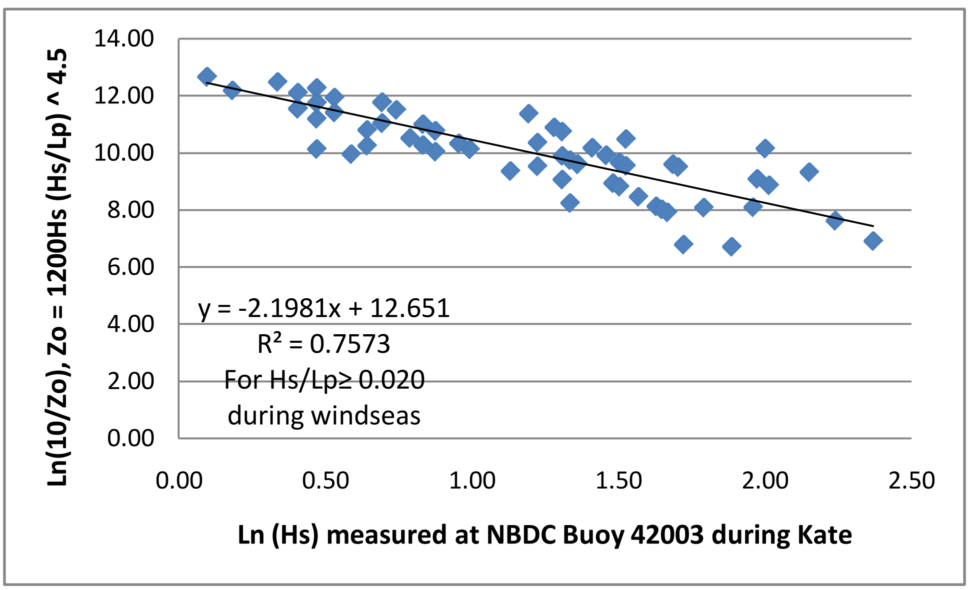

Figure 2 : A relation between sea surface roughness, Zo, and Hs during Kate

Table 2 : Wave measurements at 52200 near Guam during Typhoon Man-Yi In July 2007by Scripps Institution of Oceanography (www.ndbc.noaa.gov)

Day	Hour, UTC	Hs, m	Tp, sec	Hs/Lp	Ln(Hs)	Ln(10/Zo)
7	13	1.4	5	0.036	0.34	9.8
7	15	1.5	6	0.027	0.41	11.1
7	16	1.4	5	0.036	0.34	9.8
7	17	1.4	6	0.025	0.34	11.5
7	18	1.5	6	0.027	0.41	11.1
7	19	1.5	6	0.027	0.41	11.1
7	20	1.6	7	0.021	0.47	12.1
7	21	1.5	6	0.027	0.41	11.1

7	22	1.6	7	0.021	0.47	12.1
7	23	1.6	7	0.021	0.47	12.1
8	0	1.7	7	0.022	0.53	11.8
8	1	1.7	7	0.022	0.53	11.8
8	3	1.6	7	0.021	0.47	12.1
8	6	2	8	0.020	0.69	12.1
8	7	2	6	0.036	0.69	9.5
8	8	2.3	8	0.023	0.83	11.3
8	9	2.3	8	0.023	0.83	11.3
8	10	2.7	8	0.027	0.99	10.5
8	11	2.9	8	0.029	1.06	10.1
8	12	3.1	8	0.031	1.13	9.7
8	13	3.3	8	0.033	1.19	9.4
8	14	3.1	8	0.031	1.13	9.7
8	15	3.5	8	0.035	1.25	9.0
8	16	3.5	8	0.035	1.25	9.0
8	17	3.5	9	0.028	1.25	10.1
8	18	3.7	9	0.029	1.31	9.8
8	19	4.2	9	0.033	1.44	9.1
8	20	4.9	9	0.039	1.59	8.2
8	21	5.5	10	0.035	1.70	8.6
8	22	5.3	11	0.028	1.67	9.6
8	23	6.2	10	0.040	1.82	7.9
9	0	6.8	11	0.036	1.92	8.3
9	1	6.3	10	0.040	1.84	7.8
9	2	7	11	0.037	1.95	8.1
9	3	6.5	11	0.034	1.87	8.5
9	4	7	11	0.037	1.95	8.1
9	5	6.8	11	0.036	1.92	8.3
9	6	6.2	11	0.033	1.82	8.8
9	7	6	11	0.032	1.79	8.9
9	8	6	11	0.032	1.79	8.9
9	9	5.4	11	0.029	1.69	9.5
9	10	5.4	10	0.035	1.69	8.7
9	11	5.2	10	0.033	1.65	8.9
9	12	5.3	11	0.028	1.67	9.6
9	13	5.2	11	0.028	1.65	9.7
9	14	5	11	0.026	1.61	9.9
9	15	5.7	10	0.037	1.74	8.4
9	16	4.8	11	0.025	1.57	10.2
9	17	4.6	11	0.024	1.53	10.4
9	18	4.6	11	0.024	1.53	10.4
9	19	5	11	0.026	1.61	9.9
9	20	4.7	10	0.030	1.55	9.4
9	21	4.6	11	0.024	1.53	10.4

9	22	5.4	11	0.029	1.69	9.5
9	23	5.4	11	0.029	1.69	9.5
10	0	4.3	11	0.023	1.46	10.8
10	1	3.9	10	0.025	1.36	10.5
10	11	2.6	9	0.021	0.96	11.7
11	18	1.1	5	0.028	0.10	11.2
11	19	1.2	6	0.021	0.18	12.3
11	20	1.1	5	0.028	0.10	11.2
11	21	1.1	6	0.020	0.10	12.8
11	23	1.1	5	0.028	0.10	11.2

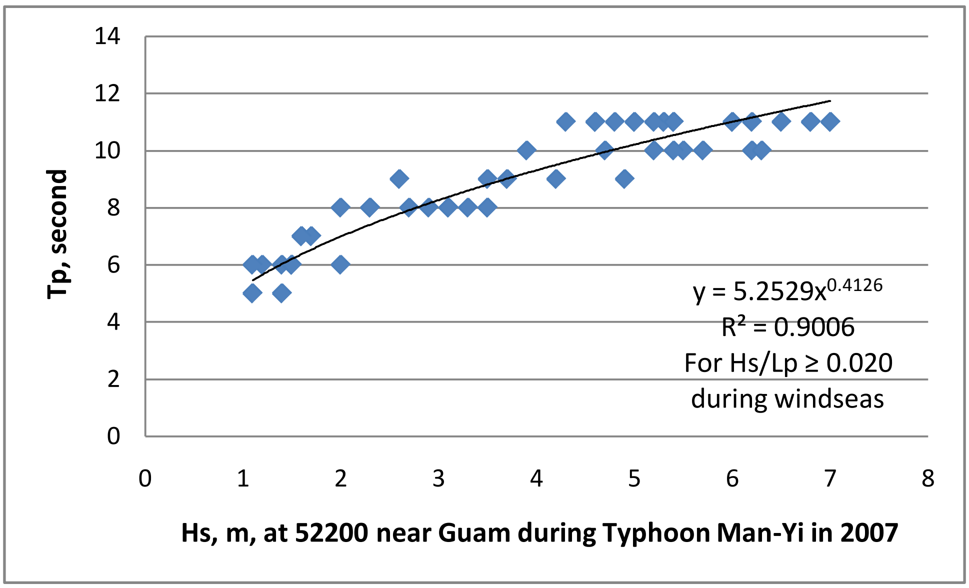

Figure 3 : A relation between Hs and Tp at Buoy 52200 near Guam during Typhoon Man-Yi in July 2007 (see Table2)

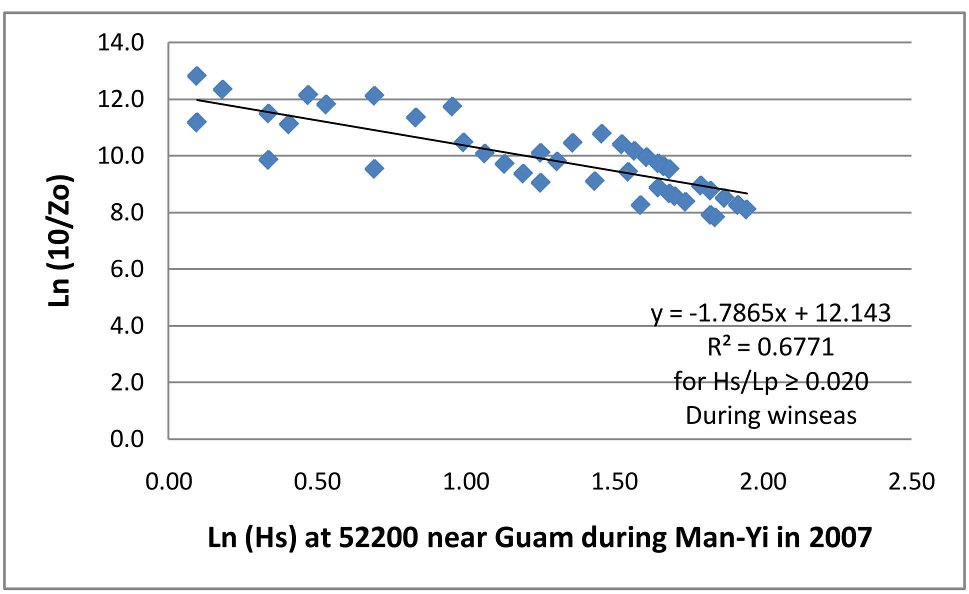

Figure 4 : A relation between Zo and Hs at Buoy 52200 near Guam during Man-Yi

III. Results

According to Eq. (1) we need to find a relation between U10 and U* before we can find the relation between U10 and Hs. This is accomplished by employing the sonic anemometer measurements made over the North Sea during storms (for details, see Geernaertet al.1987). The results are presented in Fig.5, so that

$$U^* = 0.0195\ U10 \wedge 1.285 \qquad (10)$$

A comparison of Eqs. (1) and (10) is presented in Fig. 6. Since they are nearly identical, we can say that both equations are useful. Now, from Eqs. (1), (9), and (10), we derive the relation between U10 and Hs as follows:

$$U10 = (21/(12.7 - 2.2\ \mathrm{Ln}\ (Hs))) \wedge 3.5 \qquad (11)$$

Eq. (11) is presented in Fig.7, which is further simplified as

$$Hs = 0.27\ U10 \qquad (12)$$

Since the coefficient of determination, R^2 (= 0.99), is almost perfect, Eq.(12) is recommended for practical applications.

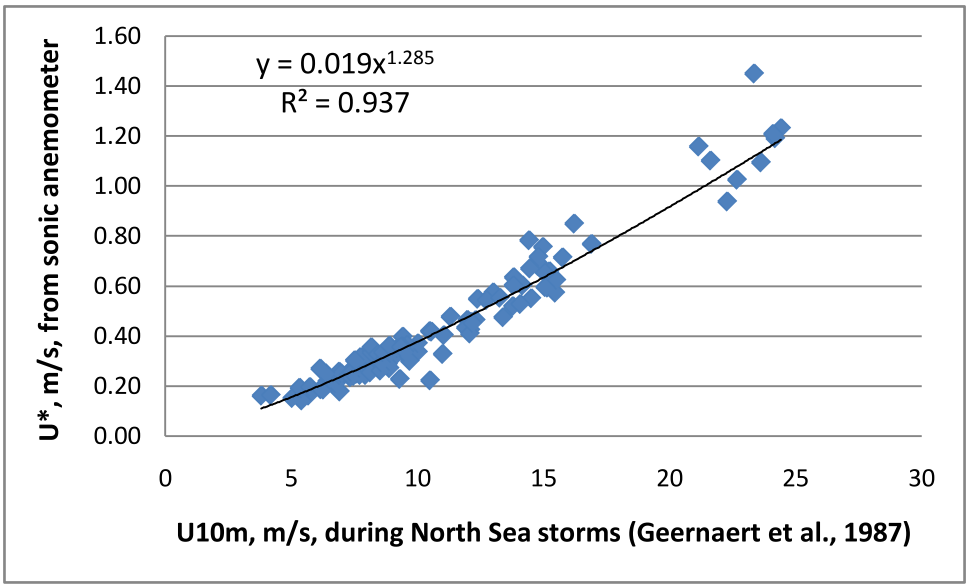

Figure 5 : A relation between U* and U10 as measured during Storms over the North Sea by sonic anemometers (Data source: Geernaert et al., 1987)

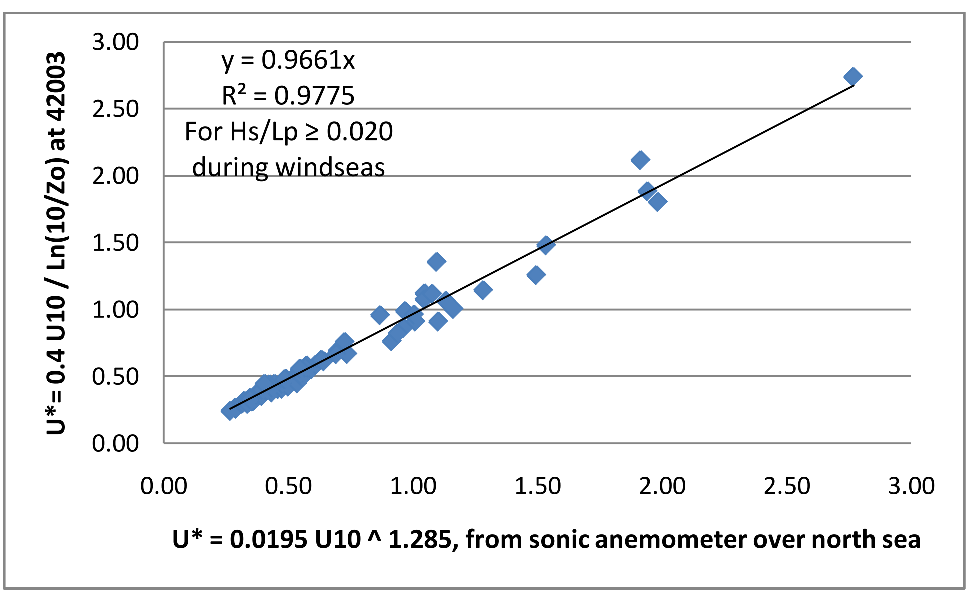

Figure 6 : A comparison of Eqs. (1) and (10) using the dataset provided in Table 1

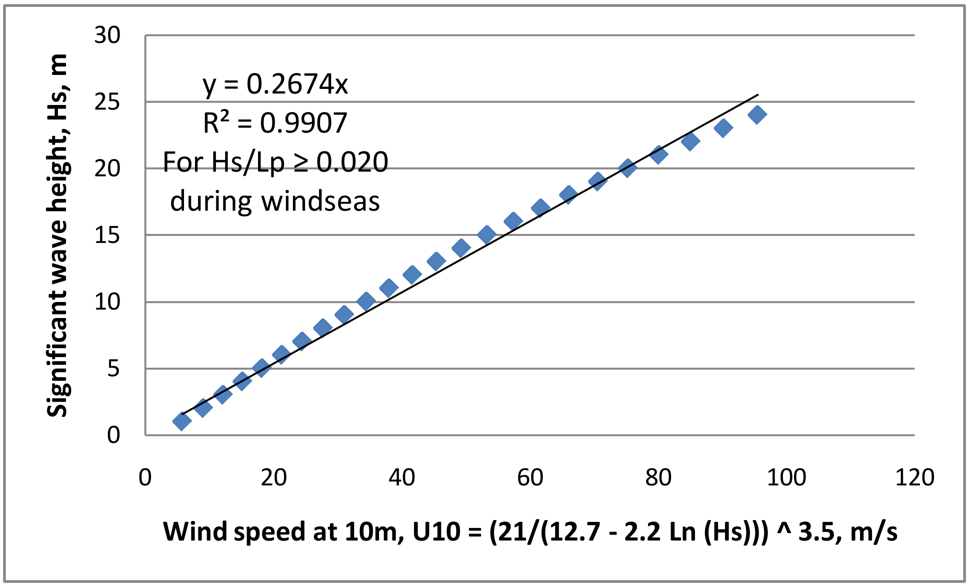

Figure 7 : A simplification of Eq. (11)

IV. Verifications

Using the data provided in Table3, Eq. (11) is verified as shown in Fig.8.

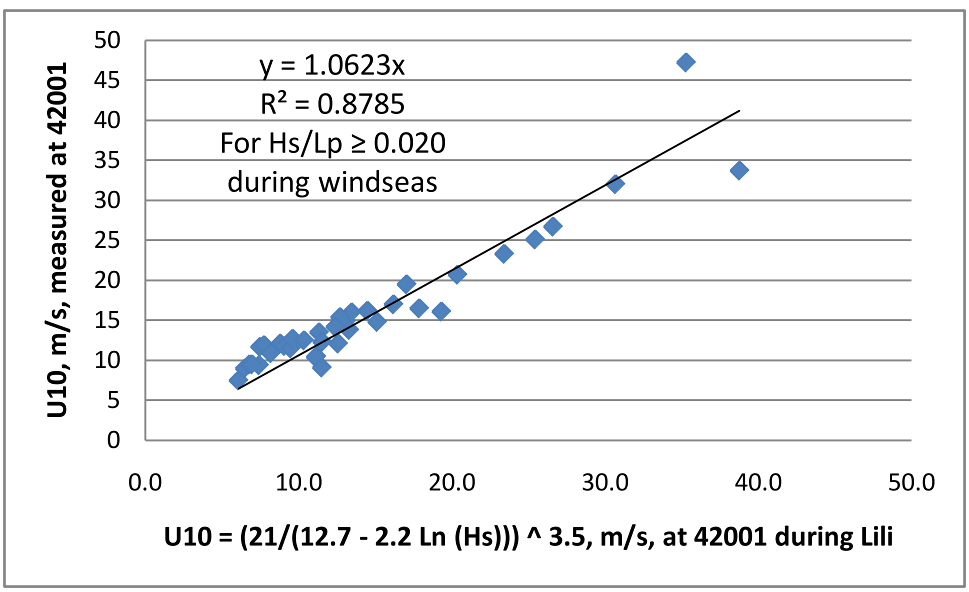

Figure 8 : A verification of Eq. (11) during Hurricane Lili based on the dataset provided in Table 3

Table 3 : Measurements of wind, wave, and atmospheric pressure at NDBC Buoy 42001 duringHurricane Lili in October 2002 (Data source: www.ndbc.noaa.gov), see text for explanations

Day	Hour UTC	Wind direction	U10m m/s	Gust m/s	Hs m	Tp second	Hs/Lp	Pressure hPa
1	15	63	6.9	8.2	1.02	5.56	0.021	1015.4
1	17	79	7.5	8.8	1.08	5.88	0.020	1014.9
1	19	68	9	10.5	1.2	6.25	0.020	1013.4
1	22	66	9.4	11.5	1.48	6.67	0.021	1012.4
1	23	77	9.5	10.8	1.29	4.35	0.044	1012.4

2	0	75	9.5	10.7	1.34	5.88	0.025	1012.5
2	1	74	11.7	13.2	1.5	6.25	0.025	1012.3
2	2	64	11.9	13.7	1.58	5	0.041	1012.7
2	3	62	10.9	13.8	1.72	5.88	0.032	1012.8
2	4	58	12.1	14.5	1.91	5.88	0.035	1012.7
2	5	54	11.8	14.5	2	6.67	0.029	1012.1
2	6	57	11.5	13.2	2.13	7.69	0.023	1011.2
2	7	64	12.7	14.8	2.17	7.69	0.024	1010.6
2	8	53	12.5	14.6	2.41	7.69	0.026	1009.1
2	10	67	13.5	16.1	2.73	7.14	0.034	1008.1
2	11	55	14.9	19.1	3.31	9.09	0.026	1007.4
2	12	49	14.8	17.4	3.98	10.81	0.022	1006.6
2	15	44	16.5	20.6	4.88	12.12	0.021	1004.8
2	16	48	16.1	23.4	5.35	12.12	0.023	1003.3
2	17	63	23.3	28.9	6.66	13.79	0.022	1000.3
2	18	61	26.7	32.8	7.65	12.9	0.029	995.1
2	19	59	32	39.1	8.88	13.79	0.030	984.6
2	20	103	47.2	65.6	10.22	13.79	0.034	956.1
2	21	158	33.7	40.5	11.2	12.9	0.043	975.4
2	22	178	25.1	32.5	7.29	10.81	0.040	988.4
2	23	190	20.7	24.5	5.69	9.09	0.044	994.2
3	0	195	19.5	26.3	4.61	10.81	0.025	998
3	1	200	17	21.5	4.33	7.14	0.054	1001.1
3	2	199	16.2	20.3	3.77	6.67	0.054	1003.6
3	3	191	16	19.2	3.43	7.69	0.037	1004.9
3	4	190	15.4	18	3.18	6.67	0.046	1006.7
3	5	186	13.8	16.6	3.38	6.67	0.049	1007.2
3	6	192	12.1	14.1	3.14	7.14	0.039	1007.4
3	7	184	14.2	16.6	3.08	7.14	0.039	1007.2
3	8	192	12.3	15.1	2.8	6.67	0.040	1007.2
3	9	191	10.5	12	2.67	6.67	0.038	1007.6
3	11	176	10.4	12.6	2.66	8.33	0.025	1009.3
3	12	169	9.1	10.6	2.79	8.33	0.026	1009.7
3	13	176	7.2	8.9	3.09	7.69	0.033	1010.9
3	15	171	8.3	10	2.65	8.33	0.024	1012.1
3	16	177	7.6	9.8	3.01	8.33	0.028	1012.2
3	17	174	7	8.3	2.71	7.14	0.034	1012.2
3	18	165	6.3	7.3	2.43	7.14	0.031	1012.1
3	19	170	5.5	6.4	2.62	6.67	0.038	1011.5
3	20	162	4.9	5.7	2.43	7.14	0.031	1011.2
4	1	152	5.9	7.1	1.84	7.14	0.023	1011.8
4	17	125	2.8	3.7	1.09	5.26	0.025	1015.7
4	20	111	4.5	5.2	1.08	5.26	0.025	1014.5
4	22	115	3.9	4.5	1.01	5.26	0.023	1014.2

Further verification of Eq. (12) for a typhoon is presented as follows:

According to the Joint Typhoon Warning Center (see Fig.9), on 6 October 2007, Super Typhoon Krosa was near northeastern Taiwan. The wind speed was 125kts (or 64m/s). Substituting this value into Eq. (12), we get the maximum significant wave height to be approximately 17m. Now, according to Liu et al. (2008), the maximum trough-to-crest wave height was measured to be 32.3m by a data buoy near northeast Taiwan in the western Pacific that was operating during the passage of Krosa.

According to the World Meteorological Organization (1998), the maximum trough-to-crest wave height may be statistically approximated by 1.9 times the significant wave height. Therefore, the maximum significant wave height is 32.3/1.9 = 17m during Typhoon Krosa near NE Taiwan. Since this value is identicalto that of 17m as obtained from Eq. (12), we can say that Eq. (12) is further verified under a typhoon condition.

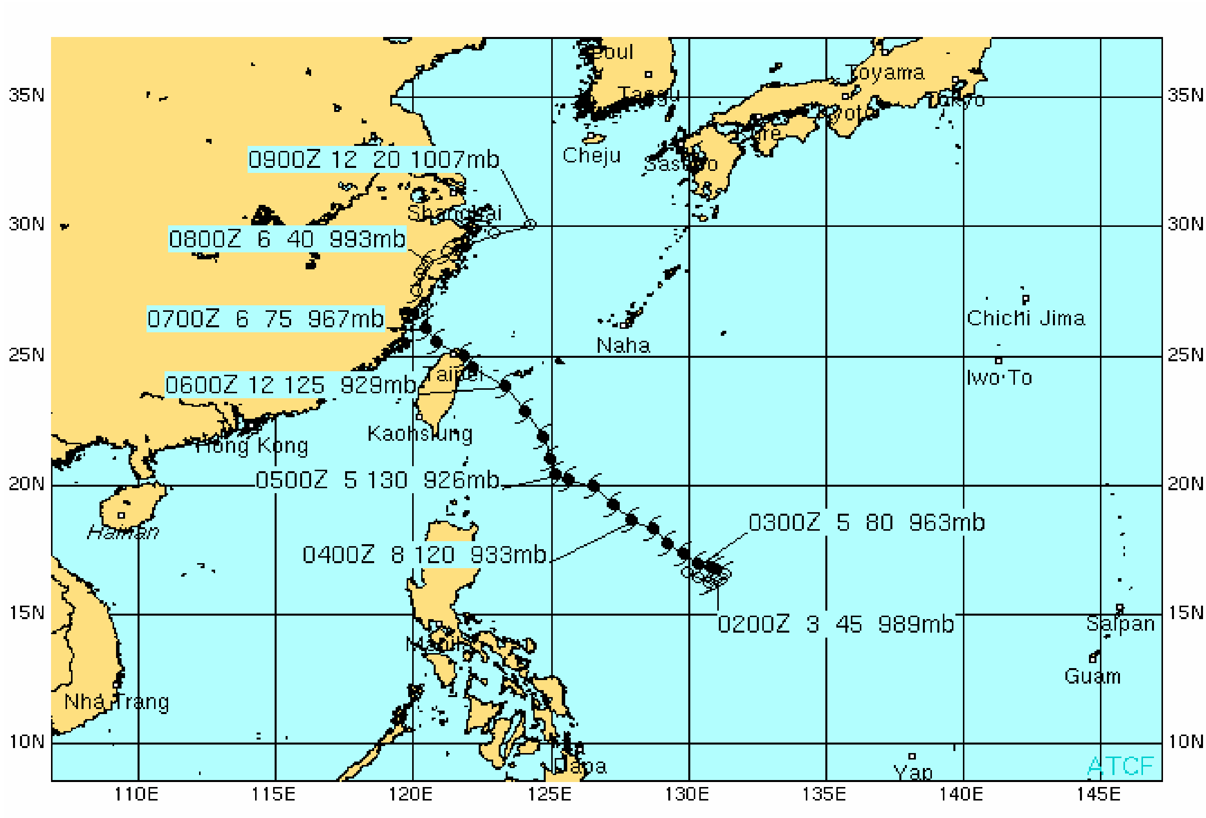

Figure 9 : Best Track of Super Typhoon Krosa in October 2007 (http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/atcr/2007atcr.pdf)

V. Conclusions

On the basis of aforementioned analyses and discussions, it is concluded that

(1) There are no appreciable differences in wave characteristics during a hurricane or a typhoon, indicating that the knowledge gained from hurricanes can be applied to typhoons;

(2) Significant wave height, Hs, and dominant wave period are related thru Eq. (5);

(3) Sea surface roughness and Hs are related thru Equations (7) and (9);

(4) The friction velocity and the wind speed at 10m are related thru Eq. (10), and finally,

(5) The wind speed at 10m and Hs are related thru Eq. (11) and for practical use thru Eq. (12).

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A Multiplier Approach to Power Generation for Remote Tropical Regions

By John C. Edmunds & Charles Winrich
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Abstract- Multiplier effects can be relevant for evaluating alternative ways of generating electricity, especially in remote regions, were the superior method might be different from the method that would be chosen in a location near transport hubs. Remote tropical regions often have easily gathered amounts of biomass, and they also have sufficient sunlight to make solar energy a competitive way of generating electricity. Remote tropical regions also have export revenues that are currently being used to import gasoline and diesel for small-scale portable generators. Recent innovations in biomass converters and solar panels make it possible for these regions to create local employment and save scarce foreign exchange, while generating electricity more cheaply. We discuss these alternatives and compute multiplier effects to arrive at promising result.

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AMULTIPLIERAPPROACHTOPOWERGENERATIONFORREMOTETROPICALREGIONS

Strictly as per the compliance and regulations of :

A Multiplier Approach to Power Generation for Remote Tropical Regions

John C. Edmunds α & Charles Winrich σ

Abstract- Multiplier effects can be relevant for evaluating alternative ways of generating electricity, especially in remote regions, were the superior method might be different from the method that would be chosen in a location near transport hubs. Remote tropical regions often have easily gathered amounts of biomass, and they also have sufficient sunlight to make solar energy a competitive way of generating electricity. Remote tropical regions also have export revenues that are currently being used to import gasoline and diesel for small-scale portable generators. Recent innovations in biomass converters and solar panels make it possible for these regions to create local employment and save scarce foreign exchange, while generating electricity more cheaply. We discuss these alternatives and compute multiplier effects to arrive at promising result.

I. Overview: In Search of a Policy for Remote Tropical Regions

Prosperity, when it comes to a country, usually shows up first in the big cities. Later it spreads to remote, far-flung parts of the country. Some of these peripheral territories receive the friendly winds of prosperity only much later, and some are so far away from the action that they never really participate. Those are regions that, for lack of infrastructure, institutions, or rapid communications, cannot put into effect the full range of economic policies that national governments can apply. Those regions are constrained to adopting local remedies, and cannot depend on extensive, well-functioning links to large cities or major avenues of trade. They have to accept macroeconomic realities, such as the exchange rate of the national currency and the (probably low) market price of their export goods, if they have any exports. These areas cover as much as 5% of the Earth's total land area, and are home to as much as 1% of the Earth's population[1].

Remote areas, and especially islands with low population density, are suitable for study because they allow researchers to see a simple, stripped-down version of an economy, in plain view without the layers of complexity and the distortions that bombard the observer who studies the economy of a modern metropolis. Thinly populated islands at the far reaches of a nation's transport system have to have simple economies because they do not have enough contact with metropolitan zones to play a supporting role in the complex metropolitan economy.

This attempt to examine simple, isolated regional economies is a modern version of an analytical approach that has a long pedigree in the history of economic thought. As the theories of economic development and human decision-making were developed, it was helpful to conceptualize an economy for an isolated region, especially an island. In particular, economists long debated the Robinson Crusoe economy, in which a single individual inhabits an island that has no trade with the outside world and never receives visitors. This single-person economy is a useful setting to discuss consumer preferences, production possibilities, and tradeoffs between production of one good versus another. In the original formulation of this parable, trade with other islands was impossible and telecommunications did not exist. In the updated version presented here, the remote region is not completely isolated, and has more than one inhabitant, but is still thinly populated and does not have much commerce with less remote regions. Trade is possible, but on disadvantageous terms, and so the remote region only exports goods that are exceptionally valuable, or which the remote region can produce with some absolute or comparative advantage. The remote region import goods, but its financial resources are severely limited, so it imports only necessities and a scant few luxuries.

Insights gained by studying simple systems can sometimes be applied successfully in more complex systems. The policies recommended here can be applied effectively in other remote areas, but would not necessarily apply in urban or thickly settled regions. Nevertheless, the discussion here might trigger constructive debate about economic systems in more thickly populated regions.

II. Starting Assumptions

To begin, assume that a natural disaster has wiped out all the buildings, production facilities, and installed equipment in the remote region. The recent

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[1] We use low estimates for the tropical lands where the policy described here might apply. As much as 40% of the Earth's surface is in the tropics, but much of that surface is covered by oceans, and the tropical land area includes dry zones and heavily populated zones. The policy described here would not apply in arid or heavily populated zones.

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Typhoon Haiyan delivered a blow to the Philippines, and left several remote islands and peninsulas completely in ruins. It set those isolated places back completely. The local populations needed humanitarian relief, and struggled to rebuild their lives. They needed to rebuild their dwellings, their infrastructure, their production of goods and services, and their trade with the outside world.

The central question of this investigation is what changes those remote regions should make in their economic systems as they recover and rebuild. Before the natural disaster, their economies were in an equilibrium that provided the bare necessities of life but not much more. These remote regions suffered outmigration and could not attract immigration, except seasonal workers who came to help with harvests but usually did not stay.

These remote regions are unable to influence macroeconomic policies, and cannot improve their bargaining power in long-distance trade. They have access to cell phones and the Internet, and can import equipment and technology from outside suppliers. They can borrow money from lenders outside the remote region, but need to be able to repay the loans. They pay taxes to the national government, but the taxes are low, and they receive little from the national government. They have exports of traditional commodities, including coconut oil and meal, cane sugar, and hemp fiber. They receive a trickle of tourists seeking adventure and solitude. But their revenue from exports is low and unstable.

We chose the Philippines for examples of remote tropical regions because that country has many remote, thinly populated islands. Many of these are only serviced by ferries departing from more populous islands. Indonesia also has many thinly populated islands, scattered over thousands of kilometers of ocean, and in other parts of the world there are many similarly remote islands, or remote regions, so the policies discussed here will potentially be applicable in many parts of the world.

The Philippine examples we chose are Dinagat Island (population 126,000 before the typhoon, land area 1036 square kilometers). Dinagat Island is close to Mindanao, and faces the Pacific, with no islands to buffer it from the typhoon's force. In the past it had mines and now has some facilities for tourists. Guiuan Town, our other choice, is at the end of a peninsula that is part of Samar Island, adjacent to Leyte Island. Guiuan Town also includes islands facing the Pacific that are strung out from the end of the peninsula. Magellan is thought to have landed on one of those islands, but they are not popular tourist attractions. Guiuan Town has an airport and is connected by road to Tacloban City. The road is 89 kilometers and runs along the coast. Before the typhoon the driving time was given as two and a half hours. The islands beyond Guiuan Town are not connected by causeways and do not have regular ferry service. Population of Guiuan was 47,000 before the typhoon and its area, including the islands, is 175 square kilometers. Guiuan Town therefore includes areas that are extremely remote. Both Dinagat Island and Guiuan Town are remote enough so that policies discussed here would probably be applicable.

III. Energy Production as the Starting Point

The policy that we propose begins with energy production and delivery. Energy production is a challenge for remote areas that do not have oil or natural gas. If energy can be produced in remote tropical regions, producing it generates employment, raises output of goods and services, and can provide the means to improve the quality of life. The advantage of producing energy locally depends on the costs and also on the availability of suitable production systems.

In the remote tropical areas selected, energy production, before the typhoon, mostly involved imported gasoline, propane, and diesel fuel. Electricity came from generators that ran on gasoline or diesel, and vehicles used those same fuels. Stoves burned propane or firewood. There was hydroelectric potential, but only small amounts. Draft animals pulled ploughs, carts, or turned windlasses. The energy consumption per capita was low, on the order of 1.5 kWh per day, or 5,000 Btu per day[2]. That compares to the average of 30 to 90 kWh per day consumed in the rich countries[3].

How should remote tropical regions generate electricity and produce liquid fuel, or should they import liquid fuel to supply 100% of their needs including electricity?

There are at least five ways that remote regions can produce electricity: hydroelectric dams, solar panels; windmills; fuel cells; and biomass conversion. We ignore hydroelectric dams in this discussion because if suitable sites exist, it is usually cheapest to take advantage of the potential, and supply part of the region's electricity needs that way. We investigate the remaining four ways, concentrating on biomass conversion. For decades these alternate technologies could not compete with gasoline and diesel. They were

[2] According to the CIA World Factbook, the average daily electricity consumption per capita in the Philippines was 1.45kWh per day

[3] Calculation based on 2500 kwh per month for residential consumers and 30% of total energy use in residential. The range 30 to 90 kwh is to allow for rich countries that use energy intesively in their manufacturing sectors. If we use kwh as an aggregate metric; we should include propane or firewood for cooking, draft aninls for hauling loads, etc., and convert to kwh equivalent. If we include those other energy sources, the figure might reach 5 kwh per capita per day. Note that the figure 1.5 kwh per day of electricity consumption includes Manila and Cebu City. Excluding those two would lower the average to as little as 1 kwh per capita per day.

more expensive and required frequent attention to devices that local mechanics did not know how to fix. Recent changes in prices of hardware and the cost of oil, however, have made the cost calculations come out differently. In view of the new cost ratios, all four need to be considered.

The price of solar panels has fallen rapidly -- 99% since 1977, and 60% since 2011. The cost of installing a 1 kW system for a U.S. residence has fallen to less than $6000, and the cost of installing a 10 kW system for a larger user is less than $50,000[4]. For the U.S., those capital costs equated to a cost per kilowatt-hour of between $0.19 and $0.29[5]. Operating costs are zero, and maintenance costs are included in the calculation.

Those figures might sound low enough to induce businesses in the two remote tropical regions to switch to solar generation, and keep their gasoline and diesel generators for backup capacity. But the cost of the solar equipment would be higher because of transport costs and markups. Also the rate of discount used in U.S. calculations is too low for remote regions like the two in the Philippines. Capital is scarce in rural tropical regions, and the cost advantage of solar disappears if we use a higher discount rate. So we consider solar a potential competitor as a way of generating electricity, but not yet competitive enough to displace gasoline and diesel generators.

The exception is solar lamps. These compact units use LED lighting, and have a hand crank as a backup for days when the sky is cloudy. These are cheap, costing $20 or less, and will be part of the overall energy mix for regions like the two in the Philippines.

Wind power is the next technology that might be installed as a source of electricity for remote areas like the two discussed here. Commercial-scale wind turbines have achieved very low costs per kWh -- as low as 8 cent per kWh in New England, with reports of 6 kWh for other U.S. regions[6]. These arrestingly low costs, however, are for huge turbines, rising over 150 meters above the ground; and the installations have at least six such huge turbines, and more often have ten. Smaller turbines, rising only 50 meters above the ground, cannot generate electricity as cheaply. And no investor would build a tall structure on islands exposed to the full force of Pacific typhoons.

Fuel cells are the third technology that remote regions might install to generate electricity. These can use propane or diesel fuel as their input, and they are quickly achieving lower cost per kWh generated, so they might be part of the new energy production facilities. We also include hydrogen fuel cells. Those are particularly promising, because hydrogen can be produced via biomass conversion. We discuss this possibility more fully below, as a variant of biomass conversion.

Biomass conversion is the fourth technology to be considered and the one that we examine more thoroughly. To evaluate it properly requires calculating secondary effects. The other technologies considered, namely hydroelectric, solar, wind and fuel cells that operate on propane or diesel all would operate as if the electricity were arriving from a distant source, with minimal local employment and no local production of inputs. The remote regions would obtain electricity by sending money away, either for hardware, spare parts, or fuel. In contrast, biomass conversion would involve local harvesting of green material for the digesters to consume. It would then deliver methane, hydrogen, ethanol, or biodiesel. It would also produce compost fertilizer. The employment and production linkages are important parts of the calculations that we present in this paper.

Biomass conversion, to be properly analyzed, will require an evaluation that includes employment and consumption effects because it would have so many secondary and tertiary effects. It not only would generate local employment, it would also increase local discretionary income. By using local renewable resources to partially substitute for fossil fuels, it saves foreign exchange. The remote region would not have to send its money away to buy so much fuel. The analysis of biomass conversion will also require agronomic analysis, because the feasibility depends on production conditions for biomass, including yield per acre of dry weight, distance to haul the biomass, its composition of woody material, and the average quality of the methane, hydrogen, ethanol, and biodiesel it produces. The analysis will also need to take into account the value of the residue that is left in the digesters after all the fermentable material has been consumed. This residue is fertilizer that can be applied to increase production of export crops or to speed the growth of more biomass.

IV. From Energy Production to Improvements in the Quality of Life

For regions where biomass conversion is advantageous, the policy described here will lead to greater availability of electricity and liquid fuel. To estimate the effect on income per capita, we use price elasticity of demand and income elasticity of demand. Using one of these and then the other, it is possible to disaggregate the total response into components, and also possible to distinguish short run response from long run response.

[4] The cost of installing solar panels has dropped, but it is hard to obtain accurate estimates because subsidies are sometimes included and sometimes excluded.

[5] Several installations in the Southwestern United States have achieved "grid parity" in the sense that their cost of producing a kwh is the same as, or lower than, the cost the local electric utility charges.

[6] For New England there have been announcements of two large wind turbine projects, one on a mountain ridge in New Hampshire and one about 50 miles inland in southern Maine.

As a starting point, before the typhoon assume that electricity cost about US $0.40 per kilowatt-hour. That assumes the diesel fuel or gasoline delivered to either of the two remote regions would cost about US$ 1 per liter. The gasoline or diesel generators would operate at 25% to 35% efficiency, so could operate profitably if electricity can be sold for a price in the $0.40 range[7].

Now assume that the cost of electricity in the remote tropical region declines to $0.20 per kilowatt-hour. The immediate effect for a person consuming 1.5 kWh per day would be to release some of the money the person was spending on electricity. The person would have an increase of $0.30 per day to spend on other things. Note that 1.5*(0.40 - 0.20) = $0.30.

That calculation leads into the next calculation, which is the price elasticity of demand for electricity. In the short run, demand for electricity is inelastic, with a 1% reduction in price leading to an immediate increase in demand of only 0.2%. The reason is that consumption patterns are set, and take time to adjust. Over the longer term a 1% reduction in the price leads to a 0.9% increase in consumption. Applying those elasticities, and assuming they apply for large changes in price, the price effect would mean that there would be a quick increase in consumption from 1.5 kWh per day to 1.8 kWh per day, and over a longer time the increase would be from 1.5 kWh per day to 2.85 kWh per day.

The next calculation is to estimate the multiplier effect of the windfall increase in discretionary income. The population of the remote region would spend less on importing gasoline and diesel fuel. How much local economic activity would this savings generate? The local population of the remote region would range widely in propensity to consume. So to estimate the aggregate increase in demand for goods and services we consider different levels of propensity to consume. At the same time we consider different levels of propensity to consume imports. Imports, in the classical analysis of the multiplier effect, are treated as a leakage of purchasing power outside the region. For purposes of the analysis here, we accept this view of leakage, and that allows us to compute the following table:

V. Multiplier Effect of Economizing on Imported Fuel

A single entry in the table is: Marginal propensity to consume 0.9 and marginal propensity to import 0.4 gives

	Propensity to Consume			
		0.7	0.8	0.9
Propensity to Import	0.4	1.4	1.7	2
	0.5	1.3	1.4	1.7
	0.6	1.1	1.3	1.4

Multiplier = 1/(1-(0.9-0.4)) = 1/(1-0.5) = 2.

So the improvement in discretionary income, when the multiplier effect is taken into account, can be between $0.33 and $0.60 per day. That assumes that the per capita consumption of electricity was 1.5 kWh per day, at a cost of $0.40 per kWh, declining to $0.20 per kWh because cheaper technologies for generating electricity are implemented.

For purposes of keeping the scope of this paper narrow, we assume that the improvement is modest and would most likely not be dramatic enough to attract immigrants to the remote regions, but it would deter emigration. Therefore we assume that the population of the two islands does not change in response to the lower cost of electricity.

The next calculation is to estimate the jobs created. These jobs can be classified as direct employment, harvesting the biomass, and indirect jobs, created because of the increase in discretionary income. It is important to note that the jobs to be created are year-round work, not seasonal. In zones with plantation export crops like sugar cane, there is a harvest season, and the rest of the year there is much less demand for labor.

To compute employment effects, and to give information that underpins the cost ranges per kilowatt-hour, it is helpful to give an illustration of a biomass conversion technology, or family of technologies, that is currently being offered by commercial vendors.

VI. Biomass Conversion Technologies

For remote tropical regions, biomass is abundant and quickly regenerates after being cut and hauled away. Processes to convert it into valuable outputs can be classified according to chemical reactions and steps to produce final outputs. The simplest and most widely applied biomass conversion technology is to produce methane. Biomass digestion to produce biogas conversion is a growing field of interest. Biomass digestion is valuable because it can be used not only to dispose of unwanted wastes (e.g. Maroušek, Zeman, Vaníčková, & Hašková, 2014)to produce energy, but the biproducts from a digestion system can also be valuable in themselves (Maroušek, 2014).

We can estimate the amount of methane obtained from anaerobic digestion of plant matter using the equation from Buswell and Mueller (1952).

[7] The calculation is as follows: A gallon of No. 2 diesel fuel contains 129,000 btu of energy. There are 3.79 liters per gallon. One kilowatt-hour of electircity is equalivalent to 3,413 btu, so a liter of diesel fuel, converted to electricity at 100% efficiency, is 9.9 kilowatt-hours. Converted at 25% or 35% efficiency, one liter of diesel fuel gives 2.49 to 3.49 kwh. So if a liter of diesel fuel costs $1.00, then the cost per kwh of electricity would be $0.29 to $0.49.

$$C_nH_aO_b + (n\text{-}a/4\text{-}b/2)H_2O \rightarrow (n/2\text{-}a/8+b/4)CO_2 + (n/2+a/8\text{-}b/4)CH_4$$

Using the composition of corn silage as a typical plant matter (45% O, 44% C, and 6.3% H by weight) the equation gives a composition of the resulting biogas of 51% methane. Assuming the plant matter is 80% water, one metric ton of plant matter would yield 200kg of dry material, of which 88kg would be carbon. Not all of this carbon would be converted to gas in the anaerobic digester, but 60% of the carbon content could be converted into biogas. This would produce 35kg of methane gas per metric ton of wet material put into the digester, with an energy content of 1809MJ, or 502kWh. This gas can be burned gas in a stove to cook or in a gas-powered refrigerator. Or the methane can be burned to generate steam for a turbine to generate electricity. Our focus is on generating electricity, and in this case, a traditional steam turbine (~35% efficient) would produce approximately 176kWh of electricity from one metric ton of biomass. If used as part of a combined heat and power (CHP) plant, the total efficiency jumps to 85%, with 176kWh of electricity produced, and the remaining energy available as heat for use in other applications.

Another alternative is to use a fuel cell to produce electricity. Fuel cell systems exist that include internal fuel reformers, so they can operate on a hydrogen-rich fuel like methane. These systems are slightly more efficient than electrical turbines (about 40%) so the biogas produced from one ton of biomass would yield 201kWh of electricity from such a system. Similar efficiency gains to those noted above can be achieved in a fuel cell based CHP plant.

A second alternative exists for fuel cells: steam-reform the methane into hydrogen, and then use a fuel cell to convert the hydrogen to electricity.

$$CH_4 + H_2O\ (+heat) \rightarrow CO + 3H_2$$

The carbon monoxide will then react with the steam to produce additional methane:

$$CO + H_2O \rightarrow CO_2 + H_2$$

If we assume the output above of 35kg of methane above, the steam reform process should yield 17.95kg of hydrogen gas, of which 8.98kg came from the methane, and the rest came from the steam. The steam reformation process takes place at high temperatures (~800C) and pressures (3-25 bar), and thus represents an energy input to produce the hydrogen in excess of that contained in the methane. However, the hydrogen produced by such a process, used in a typical (~60% efficient) fuel cell would yield 425kWh of electricity from one metric ton of biomass.

The system that we describe here is offered by at least two commercial vendors. It is discussed here for purposes of illustration, not to recommend any technology or any commercial vendor. It is only one design among many that are available. The system includes a pre-fermentation chamber, where the freshly cut biomass is transformed via hydrolysis, with heat and pressure, to simpler molecules, more accessible to anaerobic conversion. That design delivers higher yields.

The system that we have chosen as an illustration is large. It is intended to be sold to operators of large farms that produce steady quantities of biomass. It includes a pre-fermentation container, where hydrolysis breaks down the polymers in the raw material input (long chains of cellulose) and converts them into monomers. Once they are in that simpler state, the fermentation process can convert more of the available glucose.

Economies of scale are important in any chemical process, so we do not assert that smaller scale systems can produce the same cost per kWh. However, smaller scale systems have the advantage of a lower initial investment.

The system that we describe would use 205 metric tons of biomass per day. That is the output from 1500 hectares of land. By assumption, the land is not being used for crops, and the local inhabitants consider it marginal or useless. The land produces 50 metric tons of vegetation per hectare per year. That is with one harvest per year. More frequent harvests might produce more yield per hectare, but we do not include that possibility. We also assume that laborers are available to cut and transport the biomass to the site where it will be converted.

The system that we describe would produce 425 kWh of electricity per ton (wet weight) of biomass. That would give 31,875,000 kWh per year. That amount of electricity would supply more electricity than the current consumption of the entire population of Guiuan Town and the islands next to it. Two systems of the type we describe would supply more electricity than the current consumption of the entire population of Dinagat Island. If we leave off the steam reformation plant, we can still generate 201kWh of electricity per ton of biomass, or a total of 15,075,000 kWh per year. This would still allow the addition of a hydrogen plant later.

Details of the system, including a diagram of the hydrolysis processing, the hydrogen separation equipment and fuel cell equipment, are in Appendix I. In Appendix 2 we give sensitivity analysis to the estimates of yield and conversion efficiency. Those, in turn, lead to a range of estimates of cost per kWh.

We chose to highlight this technology because the costs of implementing it make it competitive with imported liquid fossil fuels. We now consider the costs of harvesting biomass and transporting it to the processing plant, and arrive at a range that is discussed and computed below.

VII. Direct Employment Effects

All biomass conversion technologies will depend on the cost of cutting and transporting biomass. To arrive at a figure of how much can be paid to workers who cut and transport biomass, we use a method which pays the avoided cost to the local workers.

To begin, we assume that a man can cut about one-third of a hectare per day.

To harvest 1500 hectares would therefore require 4500 man-days. Using 220 working days per year per man, that is approximately 20.5 man-years to cut the biomass. We add 5 more man-years to include transporting the biomass of the processing plant.

What would be the avoided cost of this system? If we assume that this system can produce 31,875,000 kWh per year, and the cost of generating that amount of electricity with small diesel and gasoline generators is $0.40 per kWh, then the value of the electricity produced would be US$ 14 million per year. If local users would pay only $0.20 per kWh for electricity produced by this system, the value of the system would be US$ 6.375 million per year. Note that 31,875,000 * (0.40 - 0.20) = $6,375,000.

If we exclude the steam reformation equipment, the annual avoided cost is lower, but so is the cost of hardware and installation. The process without steam reformation would generate 15,075,000 kWh per year. At a cost of $0.40 per kWh that much electricity would have an annual cost of $6.03 million per year. If we pay only $0.20/kWh by using this system, the annual savings would be $3.015 million per year. After paying the workers according to the terms proposed below, their remaining amount of avoided cost would be $2.765 million.

If we pay the laborers US$ 10,000 per year for the arduous work of cutting and transporting vegetation, we use only $250,000 of the theoretical savings, leaving (in our most complete version of the system to be installed) $6.125 million to be allocated to other uses. That $10,000 annual wage is slightly more than double the GDP per capita of the Philippines. Part of the $6.125 million would be needed to compensate the commercial vendors who produce and install hardware.

The cost per kilowatt-hour for this system would be very low. The only direct cost that we have stated is the wages of the laborers. That would be only about 1.7 U.S. cents per kilowatt-hour. To arrive at a more complete cost figure, it would be necessary to include a cost of the equipment, including installation and maintenance. Some analysts would also include a payment to the owner of the land where the biomass grows, but we do not include that because we assume that the land has no economically important alternate use.

This calculation implies that biomass conversion technologies are potentially very competitive with imported fossil fuels. The yields, conversion factors and efficiency of currently available systems can be much worse than the figures we use here, and biomass conversion still would be very competitive with electricity generated by importing diesel and gasoline. The newer designs make available more of the potential chemical energy in the biomass.

In view of these calculations, it appears that these remote Philippine islands, and similar regions, should consider installing larger-scale alternatives for biomass conversion. They should also consider that smaller scale biomass conversion might be almost as competitive, and much easier to obtain, install, and operate. The land area that we chose 1500 hectares, equivalent to 15 square kilometers, is 1.5% of the land area of Dinagat and 8.6% of the land area of Guiuan.

If more land and labor are available, these islands can produce more electricity, and find new activities that would use the electricity.

VIII. Solar Alternative

Before concluding that biomass conversion is superior to other alternative energy generation technologies for remote tropical areas, we offer data about cost and output of solar panels. The price of solar panels has declined sharply, and the efficiency has also improved. The costs and efficiency are changing rapidly, so we only give a range. Solar has the advantage relative to biomass that, once the panels are installed, they should operate for years with little or no maintenance. Solar is also easily scalable, perhaps more easily than biomass conversion: solar installations can be set up in arrays of different sizes that are the right size for the demand in the immediate area. The arrays can be increased as needed, and the new arrays will be as productive, or more productive, than the ones that were installed earlier.

The data for cost per kilowatt-hour that we have found does not consider economies of scale. This indicates that economies of scale are less important than for chemical processes that use cylindrical or spherical containers to process volumes of material. What does matter is the average latitude because that affects the amount of solar energy that can potentially be collected per unit of area.

The regions and cost ranges are as follows:

United Kingdom	US$ 0.12 - US$0.18
Germany	Euro 0.078 - Euro 0.14
United States	US$ 0.06 - US$ 0.59 (the range includes PV and CSP)
United States	US$ 0.101 - US$ 0.2009

These data indicate that solar panels can compete with gasoline or diesel generators, and can also compete with biomass conversion. The cost advantage of solar has been increasing, especially when tax incentives are taken into account. The cost advantage, especially if recent trends continue, will make solar panels a more widely adopted alternative.

IX. Additional Economic Considerations

To make this brief discussion more complete, we should note that biomass conversion produces compost fertilizer, and some processes also produce high protein animal feed. We have not considered these by-products because the calculations indicate that, even without the by-products, conversion is apparently competitive. We do include the hydrogen gas obtained via the steam reformation process, because it would be converted into electricity. For each total system, it is always necessary to define what are the boundaries of the system. We exclude the fertilizer and animal feed because our focus is on electricity output. Also, the calculations show a cost advantage that is large enough so that valuable by-products do not need to be taken into account.

The economic activity described here would have multiplier effects, in the sense that the workers who cut the biomass would spend their income on the island, and the money would circulate on the island before going away to pay for imports. The multipliers we computed above are in the range of 1.1 to 2.0. That implies that each direct job could create 1 to 2 more, so the total employment effect could be as large as 75 jobs, or if Dinagat Island installs two systems of the sort described, total employment would be increased by as many as 150. There might also be increases in agricultural production and exports, as a result of increased mechanization or application of compost fertilizer. It is tempting to speculate how the additional amounts of cheaper electricity would lead to new activities and higher quality of life.

X. Conclusion

Remote tropical regions can consider a range of technologies to generate electricity. The historical choice of diesel and gasoline generators now has credible challengers, namely biomass and solar generation alternatives. The efficiency of biomass conversion has been boosted by hydrolisis pre-cookers and the price of solar panels has dropped sharply. In addition to cost advantages, biomass conversion creates local employment, and has multiplier effects that are presented here.

The multiplier effects illustrated and computed here are only the classic ones from conventional macroeconomics. It is possible to extend the multiplier effects to include possible future benefits that would arise if the remote regions generate surplus electricity. It is also possible to compute effects on CO2 recapture, but we have truncated at the multiplier effects at the boundaries that are conventional in economic literature.

Despite these constraints on the possible benefits, we obtain results that are clearly competitive with conventional fossil fuel technologies, which justify implementing medium-scale implementation in sites with favorable attributes.

Appendix 1 - Diagram of the Hydrolysis - Hydrogen to Electricity Process

The overall process of producing methane from biomass is diagrammed in figure 1. The anaerobic production of methane relies on methanogentic organisms in the final step. The methanogenetic bacteria, which are the same organisms that exist naturally in ruminant animals, primarily process acetic acid to produce methane (Ostrem, 2004). Depending on the particular biomass input, acidogenetic and acetogenetic bacteria will produce acetic acid for the methanogenetic bacteria to process.

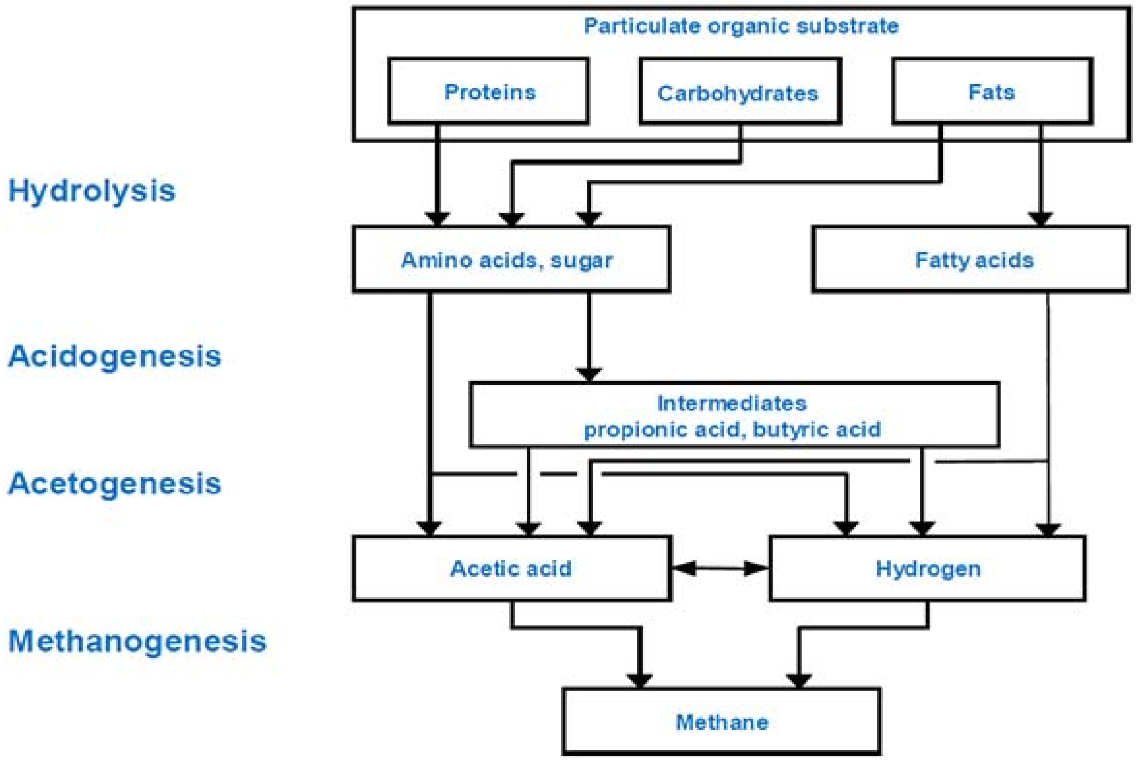

Figure 1 : Anaerobic digestion (Serna, 2009)

The hydrolysis stage is where the complex polymers (eg. Carbohydrates) are broken down into simpler organic monomers (eg. Glucose) which are more readily digested by the bacteria in the later stages. By separating the hydrolysis stage into a separate "pre-digestion" stage, the hydrolysis can be run at higher temperatures and pressures that are more favorable to those reactions occurring rapidly.

It is worth noting that pretreating the vegetative material before it enters the bioreactor can enhance the biogas production from such a system. In the text, we chose corn silage as the analog for vegetation. It has been shown that with corn silage, a hot water maceration process can be used to remove material that will inhibit fermentation and enhance gas production (Maroušek, 2013). Maceration has been shown to be effective with other plant feedstocks as well (Maroušek, 2013b; 2013c) so even though we assumed corn silage was a representative feedstock, such a component would likely be useful in our system.

Appendix 2 - Sensitivity Analysis

The overall equation for calculating the cost per kilowatt-hour of electricity in this project is:

$$Cost = (22\ workers) \times (\$10{,}000\ \ annualsalary/worker) \times [(Mass/hectare)]^{(-1)} \times [(hectares\ used)]^{(-1)} \times [(Biogas\ methane\ content)]^{(-1)} \times [(\ldots$$

Where the constants are:

88kg carbon per ton (wet) of biomass;

Carbon is 12/16 the mass of a methane atom; and

Methane contains 13.98kWh of energy per kilogram

$$Cost = \frac{Workers \times salary}{M_a \times A \times F_{methane} \times Eff_{digest} \times Eff_{elec} \times F_{Carbon} \times M_{\frac{c}{methane}} \times E_{methane}}$$

Where:

M_a is the annual mass harvested per hectare;

A is the area harvested in hectares;

$F_{methane}$ is the biogas methane content;

Eff_{digest} is the percentage of carbon converted to methane in the anaerobic digestion process;

Eff_{elec} is the efficiency of the electricity conversion;

F_{Carbon} is the fraction (by mass) of carbon in the biomass (treated as a constant, 88kg/wet ton);

$M_{c/methane}$ is the mass fraction of carbon in methane (constant, 12/16);

And $E_{methane}$ is the energy content of methane (constant, 13.98kWh)

In our least favorable case (using the biogas to power an electric generator) the conversion rate is 35%. We consider this as the base case for our sensitivity analysis. We consider varying terms in the denominator as possible variations in the system we propose. In this case, and OAT sensitivity analysis is straightforward: the reduction of any term by a factor of *x* causes a resulting increase in the cost by the same factor *x*. In the table below, we consider cases in which all our estimated factors are too favorable.

	Annual Mass per Hectare (tons)	Hectares in production	Biogasmethanecontent (%)	anaerobicconversionefficiency (%)	electricconversionefficiency (%)	Final cost ($/kwh)
Nominal assumptions	50	1500	51	60	35	0.00190
Each factor 10% less favorable	45	1350	45.9	54	31.5	0.00321
Each factor 20% less favorable	40	1200	40.8	48	28	0.00579

We also consider the possibility that we have underestimated the labor required to keep the system operating:

5 additional workers						
	Annual Mass per Hectare (tons)	Hectares in production	Biogas methane content (%)	anaerobic conversion efficiency (%)	electric conversion efficiency (%)	Final cost ($/kwh)
Nominal assumptions	50	1500	51	60	35	0.00228
Each factor 10% less favorable	45	1350	45.9	54	31.5	0.00386
Each factor 20% less favorable	40	1200	40.8	48	28	0.00695
10 additional workers						
	Annual Mass per Hectare (tons)	Hectares in production	Biogas methane content (%)	anaerobic conversion efficiency (%)	electric conversion efficiency (%)	Final cost ($/kwh)
Nominal assumptions	50	1500	51	60	35	0.00266
Each factor 10% less favorable	45	1350	45.9	54	31.5	0.00450
Each factor 20% less favorable	40	1200	40.8	48	28	0.00811

Note that in the worst-case scenario, that we have underestimated the required labor by ten workers, and that our assumptions about biomass conversion are 20% high across the board, the cost is $0.00811/kWh. If the electricity such a system produces could be sold for $0.2/kWh, that would still leave over half of the electricity revenue available.

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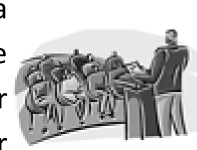

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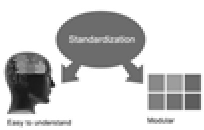

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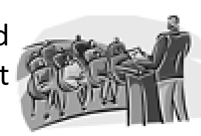

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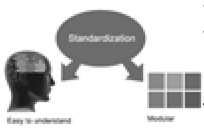

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"

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4. Manuscript's Category,

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17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

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- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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