FACTORS INFLUENCING EROSION UNDER A FOREST COVER IN RANAPUR, ORISSA STATE, INDIA

Jan-Marcus Hellström

Department of Physical Geography
GÖTEBORG 2000
FACTORS INFLUENCING EROSION UNDER A FOREST COVER IN RANAPUR, ORISSA STATE, INDIA

Jan-Marcus Hellström
ABSTRACT

This essay deals with erosion caused by rain in a forest-covered area in Ranapur, Orissa state, India. The area is under constant landuse change and is greatly characterized by the monsoon climate and is therefore interesting to study. The aim of this essay is to see what factors have an impact on erosion in the area. The hypothesis stated is that plots with trees that are about or over four meters and/or with a low sky view factor should give a high rate of erosion. Six different factors and possible causes for erosion have been taken into consideration. The factors are: number of trees, the sky view factor, slope, bush cover, crown cover and tree height.

There are a number of methods used including field studies done by Ph.D. student, Madelene Ostwald.

The results show that a thick crown cover, a high inclination of slope and a low number of trees show a correlation with erosion.
THANK YOU

I like to thank Dr. Björn Holmer for his constructive criticism and his ability to make one look at a problem from different angles and finding solutions to the same problems as well. He was also my supervisor of this essay and his time is greatly valued.

There are a number of persons and beings that I would like to thank for their help and support of all kinds connected to this essay. There is, however, one person that I am especially grateful to. This person is PhD student Madelene Ostwald at the Earth science center at the Göteborg University. She has provided me with material, ideas and contributed to this essay in a number of ways. Her constructive criticism and her views on this essay can not be valued enough. Without her this essay would never have been done Thank you.

Marie Eriksson deserves a big thank you as well for her patience as her ability to teach in showing me the technical parts of calculating the sky view factor.

Dr. Margit Werner for giving me helpful guidance with literature.
A thank you goes out to the following people and beings as well:

Peter Stille for valuable opinions on language and layout.

Frida Eek for helping me out with statistics and for being my sister in arms regarding essays, especially on Saturdays and Sundays.

All my fellow students for just, well, existing.

There are probably a number of people who have helped me that I have not mentioned here but I am a bit stressed up at the moment, so I do hope they will forgive me, I am grateful to you as well.
TABLE OF CONTENTS

INTRODUCTION.................................................................................................1

DESCRIPTION OF AREA................................................................................4

METHODS...................................................................................................7

RESULTS....................................................................................................12

DISCUSSION............................................................................................17

CONCLUSIONS..........................................................................................20

REFERENCES............................................................................................21
INTRODUCTION

The energy to move soil in a forest-covered area, primarily derives from the impact of raindrops on the soil. Soil loss is closely related to rainfall partly through the detaching power of raindrops striking the soil surface. An erosion of this kind is called splash erosion (Morgan 1995). This essay focuses on such erosion in a natural regenerated forest in Ranapur Orissa State in India.

Brooks and Spencer (1995) show that the concentration of rain on the leaves and branches maintains a more uniform drop size with most drops being between 5 and 5.9 mm, whilst open sky rainfall has a smaller mean drop size of between 1 and 2.9 mm. Other scientists have come up with similar results. Brandt (1988, p.42), for example, showed in a laboratory experiment that little difference has been found for different leaf configurations, with all drops having a size of approximately 4.5 mm. For single layer canopies, where terminal velocities can be attained, kinetic energy will exceed that of open sky situation even at low intensities of rainfall.

A canopy can change the total drop-size distribution in three ways. (1) It can alter the proportion of rain falling straight through the canopy and hence remaining unchanged. (2) It can split raindrops into smaller size or (3) combine drops into larger units (Brandt 1988, p.42). At high rainfall intensities the open sky rainfall may have larger drops and may have higher intensity than similar rain under a single layer canopy (Brooks and Spencer 1995, p.438).

In a forested area, there is little association with rainfall intensity compared to rainfall from an open sky. This is because the raindrops produced in a canopy can reach a greater mass and a greater terminal velocity, which can be reached due to the canopy height. In this way one or two large drops with the same volume of water, supply a great more energy than several smaller drops. The reason for this being “...that proportionally less energy is dissipated in overcoming air resistance by the large drop. In this way, a change of the drop-size distribution alone will change the total kinetic energy of the rain” (Brandt 1988, p.42).
An undergrowth will decrease the amount of kinetic energy reaching the ground. Low crops have been reported to lower kinetic energy up to 0.1 times that of rainfall (Brandt 1988, p.43). Moench (1991) shows that one of the key factors to control erosion and keep it down to a minimum is to have some sort of ground cover. Moench shows that the soil protection still works below four meters (fig1.).

**Fig. 1. Erosion slope and cover relationship, the plants in this diagram are below four meters. (Moench, 1991) Soil Erosion under a Successional Agroforestry Sequence: A Case Study from Idukki District, Kerala, India**

*Source: Agroforestry systems, page 39 fig.3.*

Selby (1993, p.225) states that there are seven major effects on erosion due to vegetation. Six of these are suited for a climate similar to the location of this study. The effects are:

1. Interception of rainfall by canopy as described above.
2. Decreasing velocity of runoff.
3. Root effect in increasing soil strength.
4. Biological activities associated with vegetative growth and their influence on soil porosity.
5. Transpiration of water leading to a subsequent drying of soil.
6. Compaction of underlying soil.
There are, however, other theories about how rain is intercepted by tree canopies. Goudie (1985) shows in a study from different parts of Africa, that an area covered with forest has a lower amount of erosion compared to an area that is covered with crops or barren soil. The area that was barren had the largest amount of erosion. On an average, the area that was barren had 69.1 t ha$^{-1}$ yr$^{-1}$ compared to 28.8 for the area with crops and 0.09 for the area covered with forest. According to Goudie this shows that the forest acts as the most protective mechanism against erosion.

Erosion would normally be expected to increase with increasing slope inclination and slope length (Morgan, 1995, p34). This is expected to increase velocity and volume of surface runoffs, which gives a larger amount of erosion. When raindrops fall on flat ground they splash soil particles randomly in all directions while they have a tendency to splash downslope more than upslope on sloping ground, the proportion increasing as the slope steepens.

Earlier studies in the Ranapur area show a positive correlation between tree height and high erosion (Ostwald & Näslund 1999).

The sky view factor is one method that is used to measure the amount of sky visible. In this essay it is used to measure crown cover.

The aim of this essay is to see which of the factors presented earlier have an impact on erosion in a forest in the Orissa State in India. My hypothesis is that plots with trees that are about or over four meters and/or with a low sky view factor should give a high degree of erosion. The questions asked are; is the hypothesis stated correct, if not, what other factors have an impact on erosion? The factors are, number of trees, sky view factor, slope, bush cover, crown cover and tree height.
DESCRIPTION OF AREA

The area described in this essay is located in the Ranapur area of Orissa State in India (fig.2). Orissa lies along the eastern seaboard of India and it is one of 27 states in India. Orissa is situated in the tropical belt and is under influence of the south-west monsoon. It is during the monsoon that most of the rain falls (fig.3). The mean yearly rainfall is 1542 mm (Ostwald & Näslund 1999).

36.6% of the states area is classified as forest land (Orissa Forest Department 1996). The actual forest area however, is estimated to be much smaller. This is due to land degradation of different kinds, such as degrading existing forest, leaving areas barren without vegetation or conversion to agricultural areas (Ostwald 1995). The forest of Orissa is very diversified and it is classified as a Northern Tropical Dry Deciduous forest. There are 66 different species of trees in this area (Ostwald & Näslund 1999). *Shorea rubesta* (more commonly known as “sal”) and *Azadirachta indica* (known locally as “neem”) are commonly found species, even though these were not very frequent in the study area.

The area of Ranapur is located approximately 60 kilometers south-west of the state-capital Bhudaneswar. It is about 20 kilometers north of lake Chilka Lake (fig. 2). The actual village/city of Ranapur is situated about 15 km north of National Highway 5, the main highway going from the North to the south along the east coast of India.

The topography of the area of Ranapur is characterized by plains with paddy fields; these plains have a relative relief of 5-10 meters. There are two mountain ridges that cut through the plains of the study area. These two mountain areas are the main areas for natural forest. The height of the mountains are approximately 500 meter above sea level (Ostwald 1995).

The soils represented in this area are mainly Luvisols (Ferric) and Nitosols (Eutric). The Nitosols are in an advanced stage of the weathering process giving a large amount of clay, with basic content and holds water well. The Luvisols are highly weathered and have a clay translocation that can create plinthite (FAO 1977).
Fig. 2. Location of the study (marked area along the mountain) with characteristics of Eastern Gaths with natural forest and plains with rice paddies.

Source: Spot satellite acquired on December 29, 1994 (228-309)
Fig. 3. Monthly mean rainfall and standard deviation from Ranapur weather station 1987-1997.
METHODS

The data presented in this essay was gathered by a number of different methods. These methods include calculation of sky view factors in canopies with GIS and field studies for collection of physical features. The field studies were done by Ph.D. student Madelene Ostwald who was (and still is) very kind to share her data with me.

FIELD WORK

The field work was done in 1997 and several methods were used including vegetation classification and erosion assessment. The area for the field work was randomly chosen on the basis of accessibility. The field work included 35 plots. Each plot had a radius of five meters. To identify each visited plot in map material, Ostwald used a GPS. Each tree over one meter was counted and its height was estimated. Vegetation less than one meter was regarded as sapling. Some trees were accurately measured and a person was used as a “measuring-rod” for calculating the height of the other trees. The slope angle of each plot was measured with an inclinometer. The bush and crown covers were estimated in six classes indicating ranging from 0% to full coverage (100%). The six classes are:

<table>
<thead>
<tr>
<th>Class</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>2</td>
<td>0-25%</td>
</tr>
<tr>
<td>3</td>
<td>25-50%</td>
</tr>
<tr>
<td>4</td>
<td>50-75%</td>
</tr>
<tr>
<td>5</td>
<td>75-100%</td>
</tr>
<tr>
<td>6</td>
<td>100%</td>
</tr>
</tbody>
</table>

The percentage of area affected by erosion was stated in the same six classes along with the United States Department of Agriculture (USDA) erosion classification, which indicates the severity or development of erosion (USDA 1993).
Table 1 USDA Classification of Erosion

<table>
<thead>
<tr>
<th>Class</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Slight erosion - up to 25% of topsoil lost</td>
</tr>
<tr>
<td>2.</td>
<td>Moderate erosion - 35-75% of top soil lost</td>
</tr>
<tr>
<td>3.</td>
<td>Severe erosion - 75-100% of top soil lost</td>
</tr>
<tr>
<td>4.</td>
<td>Very severe erosion - gullies</td>
</tr>
</tbody>
</table>

Since all of the plots were heavily affected by erosion, all plots with the exception of four had a class five on the six-class scale, the USDA classification was used as an erosion measurement. Bush cover and crown cover were, however, graded in the six class scale. The parameters used in this study are: bush cover, crown cover, slope, sky view factor, tree height and number of trees.

A steep slope is a slope with an inclination of 15° and over according to Young’s classification of a moderately steep slope (Young 1986, p.173). Plots with more than 15 trees were regarded as a plot with many trees whereas a plot with 15 or less than 15 trees was regarded as a plot with a few trees. This division of number of trees was done by the author of this essay.

Some sources of error can be noticed here. The human error is obviously one factor that can alter the results. A lot of the results were estimated and obviously those estimations were a bit subjective though they were aiming to be objective.

THE SKY VIEW FACTOR
The sky view factor is a factor that indicates how much of the sky that is covered as seen from the ground, by different obstacles, in this case tree canopies. The scale is from zero to one
were one indicates a clear sky and zero indicates a covered sky. There are a number of
different methods to find the sky view factor. I have chosen to calculate the sky view factor
with GIS (IDRISI), a method developed by Holmer et al. (1999) who used this method in
Swedish forests were it showed high accuracy.

Black and white fisheye images were taken from each plot. The reason for using a fisheye
image is that it shall give an equal-angular projection of the hemisphere. Blennow (1995)
shows that there are some distortion due to lens projection and restrictions due to field of
view. This distortion does not have a major result on the result (Holmer et al. 1999). This is
not taken into consideration in the scope of this study. A set of instructions were given to me
and carefully followed. A more detailed description of the processes involved follows below.
A diagram of the different methodological steps can be seen in fig.4.

IDRISI is a raster based GIS program (Eastman 1997). Since it is a raster based program it
divides the picture into an array of pixels. Since the sky view in an area with vegetation is
divided in a lot of sky patches between leaves, stems and branches, such a system will be
useful for analyzing a canopy image. The first step was to transfer the negative on to a
KODAK photo CD. Then the pictures were imported into IDRISI. After that the image center
and the radius had to be calculated. Since IDRISI is a raster based program and therefore
works with columns and rows all coordinates are calculated into these coordinates. The image
center and radius was calculated using a BASIC program that was designed by Dr. Holmer.
Three points on the edge of the pictures were chosen where two points were in different sides
of the circular picture. Values were given automatically and these were the put in the BASIC
program. Three radiuses were given and the average of these was the radius of the picture.
The coordinates for the center were given automatically by the program (Holmer et al. 1999).

The following procedure involved creating the pixel weight image. This is done because the
center of the image is the part that will have the largest value since the picture is taken in a
three-dimensional environment and the output is two dimensional.

The following step involves delimiting of the fisheye image. Areas outside the circle need to
be masked and it needs to have the same numbers of columns and rows as the weight image.
Pixels in the image have values between 0 and 255. A limit must be set up between what is sky and what is not sky. This is done by enlarging a part of the picture that contains sky and branches.

There are some sources of error in this method. For ideal results, the pictures should be taken during cloudy weather to minimize reflection of the leaves from the sun. Some of the pictures I analyzed were taken in sunny weather and a clear reflection can be seen. This means that some of the sky view factors have a higher value than they would have if the pictures would be taken during cloudy weather. This will probably have a considerable impact on the results. The images were taken in different conditions. Some were taken in cloudy weather and others were taken in sunny weather. This makes it harder to compare the images. Another source of error is choosing the limit between sky and trees (Holmer et al. 1999). This however, was not as tricky as it might seem and the limit was reset for every separately rate picture analyzed.
1. Import a scanned fisheye image to IDRISI

2. Calculation of image centre, radius and corner

3. Create the pixel weight image

4. Delimit the fisheye image

5. Find the limit between sky and non-sky pixels

6. Assign the value 1 to all sky pixels and 0 to all non-sky pixels

7. Multiply the images with each other

8. Sum the pixels to calculate the SVF

Fig. 4. Flowchart of calculating the sky view factor.
RESULTS

The impact on erosion in this forested area have several interesting results to present.
To see the pair-wise correlation between the factors, contingency tables were developed.

Table 2 Crown cover and USDA classification

<table>
<thead>
<tr>
<th>USDA</th>
<th>CROWN COVER</th>
<th>2-3</th>
<th>4-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>16</td>
<td>6</td>
</tr>
</tbody>
</table>

Notice the high frequency of thick crown cover in class three of the USDA scale.
Also worth noticing is the high frequency of thin crown cover in class two of the USDA scale.

Table 3 Bush cover and USDA classification

<table>
<thead>
<tr>
<th>USDA</th>
<th>BUSH COVER</th>
<th>2-3</th>
<th>4-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>13</td>
<td>9</td>
</tr>
</tbody>
</table>

Notice that there is a high frequency of low bush cover in both USDA classes.
### Table 4 Slope inclination and USDA classification

<table>
<thead>
<tr>
<th>SLOPE</th>
<th>&gt;15^0</th>
<th>&lt;15^0</th>
</tr>
</thead>
<tbody>
<tr>
<td>USDA 3</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>USDA 2</td>
<td>4</td>
<td>18</td>
</tr>
</tbody>
</table>

Note the high frequency of steep slopes in USDA class three.

### Table 5 Number of trees and USDA classification

<table>
<thead>
<tr>
<th>NUMBER OF TREES</th>
<th>Less than 15</th>
<th>more than 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>USDA 3</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>USDA 2</td>
<td>4</td>
<td>18</td>
</tr>
</tbody>
</table>

Note the high number of trees in the low USDA classes.
Table 6: Height of Trees and USDA

<table>
<thead>
<tr>
<th>USDA</th>
<th>HEIGHT OF TREES</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below 4m</td>
<td>above 4m</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Note that there is no correlation between the two factors.

Table 7: Sky view factor and USDA

<table>
<thead>
<tr>
<th>USDA</th>
<th>SKY VIEW FACTOR</th>
<th>&gt; 0.31</th>
<th>&lt; 0.31</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>11</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Note that there is no correlation.
Fig. 5. Sky view factor and tree height. Note that when tree height is tall, the sky view factor is low and vice versa.

However a correlation between the sky view factor and the height of the trees (fig. 5) was found as well as a correlation between the sky view factor and the crown cover (fig. 6).

Fig. 6. Sky view factor and crown cover.
The relationship between erosion assessment of USDA, bush cover and crown cover was tested (fig.7). Note that in almost all plots with a high USDA classification there is a high class of crown cover and a low class of bush cover. Also worth noticing are the exceptions.
DISCUSSION

As can be seen from the results the hypothesis stated is not correct since there is no correlation found between the sky view factor and erosion. No correlation between tree height and erosion could be found either and therefore, obviously, no correlation between the two factors and erosion.

The sky view factor showed no correlation with the USDA classification but the estimated crown cover showed a correlation with the USDA. A question that can be asked is why the sky view factor, which shows correlation with the crown cover, does not show any correlation with the USDA. One possible explanation is that the crown cover was estimated and has fewer classes to be put in to, compared with the sky view factor, which has many values and the results of the sky view factor was therefore spread out more. The pictures had quite a bit of reflection and therefore the sky view factor value was greater than it should have been. The pictures were also taken in different conditions as far as incoming light is regarded, some pictures were taken in bright sunlight and others were taken in cloudy weather. Another correlation could be found between the sky view factor and the height of the trees. This can be explained by the fact that taller and larger trees most likely have a denser crown cover than smaller trees.

The results indicate that where there is a high USDA class (class 3) there is also a thick crown cover (class 4-5). A high USDA classification seems to be linked to a thick crown cover, but a thick crown cover does not have to be linked to a high class of USDA (Table 2). Ten out of thirteen sites that had a high USDA classification had a thick crown cover. This situation is shown even clearer in table.2. The exceptions can be explained by that these three sites could be open places with a high sky view factor and therefore easily eroded. The sites with a thick crown cover but a small degree of erosion can be explained by several theories. The tree canopy could be multi-layered. This means that the drops would gather on the leaves, in the lower part of the canopy, and grow. They would however, not reach a sufficient velocity and thus causing an erosive impact that is less compared to rain drops falling from a single layer canopy. Another assumption that can be made is that the bush cover intercepts the fall of the raindrops, and in doing so hindering serious erosion as stated by Brandt (1998, p.42).
The bush cover seems to be low when there is a high degree of erosion. There are however quite a few exceptions and these can be seen clearly in table 3. The cases were the bush cover is low and the USDA is low can possibly be explained by multi-layered canopies as mentioned above.

The slope inclination had a strong correlation with USDA class three. Slopes with an inclination of 15° or more has a considerable effect on erosion (table 4). As Morgan (1995, p. 34) states, the volume and velocity of the surface runoff is increased with higher slope inclination. The number of trees in each plot also had correlation with the USDA classes (table 5). Few trees on a plot were correlated with class three of the USDA classification. More trees had a correlation with class two of the USDA classification. An explanation of this could be that the trees canopy brakes the velocity of the drops and therefore works as a protective layer. This would occur in plots with many trees. One can assume that there is a larger possibility of having trees of different heights in a plot that has more trees. In plots with less than fifteen trees, the drops had a bigger chance of achieving a larger velocity and therefore these drops can create more erosive effects. The results show that the height of the trees had no correlation with USDA erosion.

A table of what factors show a correlation with USDA can be seen below.

<table>
<thead>
<tr>
<th>Factor</th>
<th>correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>USDA-slope</td>
<td>Yes</td>
</tr>
<tr>
<td>USDA- SVF</td>
<td>No</td>
</tr>
<tr>
<td>USDA- tree height</td>
<td>No</td>
</tr>
<tr>
<td>USDA- crown cover</td>
<td>Yes</td>
</tr>
<tr>
<td>USDA- bush cover</td>
<td>No</td>
</tr>
<tr>
<td>USDA. No. Trees</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The factors have now been discussed separately in correlation to the USDA classification. But how do the erosion causing factors work together? Or do they work together at all. Does a plot with a high slope inclination and a high crown cover cause more runoff than a slope with just a high slope inclination? Does a plot with a few trees and a high crown cover cause more...
damage than just a high crown cover? There are probably more factors that effect erosion of this type. What are these factors and what effect do they have? How do different forests react on the same kind of erosion? These questions were not dealt with in this essay but they are questions that could be studied further in the quest to solve the complete puzzle of erosion in forested areas.
CONCLUSIONS

The following conclusions can be made from the results.

1. Slope inclination shows a positive correlation with high USDA classes
2. There is a positive correlation between crown cover and high classes of USDA
3. The number of trees in each plot shows a correlation with high USDA classes. The more trees in each plot, the smaller the USDA class, whereas less trees are correlated to a higher degree of erosion.
4. Tree height showed no correlation with the different USDA classifications
5. The sky view factor had no correlation with the different USDA classes.
6. The sky view factor shows a correlation with crown cover.
7. The sky view factor shows a correlation with the height of trees.
REFERENCES


A.Goudie 1985 ‘The Nature of the environment’ Blackwell 1985

B.Holmer, U.Postgård & M.Eriksson. 1999 Calculation of sky view factors in Canopies with GIS (IDRISI) Göteborg, manuscript

M.Moench, 1991 ‘Soil erosion under a successional agroforestry sequence: a case study from Idukki District, Kerala, India’ Agroforestry Systems 15 (1),


M. Ostwald 1995 ‘The Spatial Distribution of Soil Erosion in Different Forests and Its Effects’ Earth sciences Göteborgs Universitet

Ostwald & Näslund, 1999 ‘Effect on trees and soils from local protection of forest- Dhani Hill, Orissa, India’, Submitted to Journal of Environmental Management

Orissa Forest Department, 1996. Capacity Building for Participatory and Sustainable Management of Degraded Forests in Orissa’ Project document


Young, A 1972 Slopes, London, first edition