DEGRADATION AND RECOVERY OF SOIL IN TOBACCO CROPED AREAS IN DIFFERENT GEOFORMS IN A SMALL WATERSHED

Nilvania Aparecida de Mello- CEFET-PR, Doutoranda
PPG-Ciência do Solo – UFRGS nilvania@pb.cefetpr.br
Joelma Murlik, Hidrotécnia, IPH- UFRGS. Marcia
Berreta- Mestranda PPG Geografia - UFRGS

INTRODUCTION

The soil management system adopted in a watershed influences the sediment production and consequently the system quality and the environment in that is inserted. In the choice or recommendation of a soils management a lot of attention has been spared to the factors that influence the erosive process as the slope length, soil use and capacity and attendance to needs of each culture, but little attention has been dedicated to the geoforma effect in the acceleration or attenuation of soils degradation processes and recovery.

The amount of carbon present in an agricultural system probably is the best indicator of the quality of the use and kind of management that has been given to the soil. Quality is the soil capacity of to continue productive along your use, with low erosion rate and little use of inputs, maintaining the cost of the agricultural activity low. If the soil maintains these characteristics, the agricultural system will tend for the sustainability and the environmental contamination had been reduced to acceptable value.

The quality of a soil often expresses the potential that the same presents for the maintainable production of plants, resistance to erosion and maintenance of the environmental quality (DORAN and PARKIN, 1994; LARSON AND PIERCE, 1994). The more correlated factor with the quality of the soil is the total organic matter, expresses for the total carbon and its fractions (CONCEIÇÃO, 2002). This theory has been broadly proven in several theses and research projects, in what concerns about the soil productivity. The increase of the carbon in the soil increases the aggregation and the aggregates resistance, resulting in reduces in erosion rate and increase of the productivity by the efficient nutrients cycling, essential factor to the quality of the soil. In the definition of quality of the soil proposed by DORAN and PARKIN (1994) they considered that the soil presents quality when it is capable of besides maintaining your productivity, to accomplish your role in the atmosphere, in other words, to sustain life, to maintain the quality of the environment and to promote the health of plants and animals.

The primary particles of the soil, sands, silte and clay, form larger particles, the aggregates, that do the soil structure (RESENDE et al. 1997). This can be characterized as a complex system, constituted by the subsystems mineral, plants and microorganisms (VEZZANI, 2001) being the formation of the soil structure the result of the interactions among these subsystems.

The dissolution of the rocks origin the mineral phase of the soil that happens in long spaces of time (BUOL et al. 1973). The phase plants are the generating source of energy in the form of carbon, matter in the form of residues (LAL et al.1997, VEZZANI, 2001). The organic matter that is added to the soil it is transformed by the microorganisms that look for sources of energy (carbon) and nutritious for your cellular components (SNOW, 1992). PARTON et al., 1987 affirm that the decomposition doesn't happen in a homogeneous way in the soil, having compartments that results in presence of elements more easily degraded and others of larger persistence. This divide the elements formed in structural, degraded more physics than chemically, and metabolic, already altered chemically. It has great importance for the formation of structure in soil and to the possibility to identify the movement of the carbon in the environmental. The structure of soil is the resulted of the search of physical and chemical balance among the several compost and substances that appear in the soil due the interaction between the three phases or subsystems (CORNEJO & HERMOSÍN, 1996). VEZZANI, (2001) proposes that the interaction between the subsystems follows a sequence of phenomena that result in formation of structures with differentiated levels of order, from very small to large, and this sequence of phenomena is represented by the process of aggregation of the soil. The formed structural elements vary in size from nanometers to centimeters, the formation is an assigned process, in other words, the appearance of larger structures is conditioned by the formation of smaller structures (SIX et. al 2002; TISDALL, 1996) that acquire size every time larger as it increases the presence in several ways of carbon in the system (VEZZANI, 2001, JASTROW & MILLER 1997, GUPTA & GERMIDA, 1988).

The organic compositions are mainly substances and gums formed by polysaccharides. The microorganisms are more efficient than the plants in the liberation of these composed (ATLAS AND BARTHA, 1997; COLEMAN et al. 1998). These components act as a type of glue among the particles (LAL ET. al., 1997; OADES, 1989).

In aggregates larger size than 0,002mm and smaller than 0,020 mm this process continues, however the connector are composed mainly by isolated organic or that contains oxides or cations in your molecules. These composts are not attacked by the microorganisms of the soil, that tend to mineralize at the maximum the organic composts checking stability to the formed molecules, that can stay for a long time in the soil (LAL et al. 1997; GENNADIYEV, 1997, CHEN ET. al, 1997). When the carbon compost are inside the aggregate, it have great stability, because it are protected of the degradation process and, as reflex the aggregate acquires larger stability. Another important factor is that starting from this size, the organic matter can be in the shape metabolic or structural, in other words, it can come as composed already worked by the microbiota of the soil, or as granulometric fraction of organic matter not decomposed yet.

The carbon can stay in the soil in several forms, that can be classified in several ways. PARTON et al., 1987; considered the rates of mineralization of the fresh organic matter to CO^2, classifying the resulting phases in carbon active, slow and passive. The active is composed by the fresh organic matter, exudates and microorganisms, being the time of permanence of some days up to 5 years. The slow consists of the organic matter protected physically, intra aggregates or in the surface of soil colloids, or in more resistant chemistries forms. Your permanence is from 20 to 40 years. The passive corresponds the fraction physically protected, with permanence from 100 to 2000 years.

The mineralization process is highly dependent of the microorganisms, that are dependent of the type of soil management (STEVESON, 1995). Like this, certain soil management can favor the formation of an or other compost, and it can condition the forms of carbon than they will appear in the soil (GOLCHIN et al., 1997; GENNADIYEV,1997). In soils under forest for instance, there is a prevalence of lignin compositions, while in soils under intensive management system prevail the aliphatic compositions.

The division purpose to soils organic matter are based in the rescue of organic carbon content of the soil in the several forms that this can be associated to the solid phase. There are two main methods: chemists and physical. The chemicals are based on the extraction of the humic substances of the soil (ROSCOE and AXE, 2001; WAR and SAINTS, 1999; CAMARGO et. al. 1999) and the physicist in the obtaining of the functional morfodynamic fractions present in the soil.

PILLON (2000) and CAMBARDELLA, (1997) affirm that the physical division is more advantageous to study the the carbon inside the system of relationships with environmental , and to understand your functions in each one of these compartments. The methods of physical division of the soils organic matter in your majority base on the model proposed by CHRISTENSEN (1996). This model, based on a hierarchical arrangement of mineral and organic particles is based in specific mechanisms of protection and stabilization (VEZZANI, 2001

The geoform of the hillside slope also has influences in these factors. Convergent concave hillsides, fastened the pedogenetyc factors. They present soils less weathering than the divergent convex hillsides (WAR and it COINS, 1999; MESCERAJAKOV, 1977; BLOOM, 1972). This happens because in the convex profiles crawling processes prevail and in the concave the wash processes are more intense, so while in the first ones happens a slow movement of materials in the last ones the processes are faster and intense. The soil management accelerates or reduce this process. In soils under natural vegetation this difference results just in more shallow soils (they don't necessarily generate different soil classes) but with similar carbon content, because along of thousands years of formation of that environmental balance was reached. In cultivated soils these aspects acquire importance generating more fragile environmental.

The concern with the maintenance of the soil quality seeking the maintenance of the soil productivity developed along the last three decades, in way to contemplate new needs and to overcome new paradigms. The new environmental focus of the soil science went being altered of the concern of soil fertility, to the control of the soil erosion and evolution for conservation soil tillage systems and finally to the maintenance of the soil and water quality, being this last one the principal indicator of environmental quality. In these criteria didn't still interfere characteristics of great importance, as the form of the hillside and the aspects of hillsides succession in landscape. It is due the way as healthy led the classic studies of erosion, that base on the Universal Soil Loss Equation (USLE), in which the criteria of slope and length of the ramp are just meditated. Probably because the larger part of the research are be led in experimental samples of reduced size, that don't allow the reproduction of the watershed complexity.

This work was developed in a small agricultural watershed cultivated with tobacco and had as principal objective to evaluate the effect of the formats of the hillsides slopes on the degradation and recovery process of the soil.

METHODOLOGY

The study was accomplished in the pilot basin of the Arvorezinha, a city in the center-north area of Rio Grande do Sul State, in Brazil, The geologic formation are basalt of São Bento Group, Serra Geral. The relief of the area is elevated, typical of the Trapp. The soils classes are Inceptic Apludult - Lithic Aplusept - Aplic Udarent (Argissolos - Cambissolos-Neossolos in Brazilian Soil Taxonomy). The climate according to the Köppen classification is Cfb. The soil is used for agricultural activities, specially the tobacco crooping led in conventional till. The erosive processes are severe in all the watershed, due to high slope, the small depth of the soils and the inadequate soil management system (Minella, 2003).

The basin area are about 1,33 km^2 and it is linked to the Project of Environmental Monitoring of Watershed of the Natural Resources Management Program of the State of Rio Grande do Sul (RS Rural).

The adopted indicators were the total content of carbon and your fractions and the aggregate stability of three soil management systems (Conventional till, Minimum Till and No till) with different times of adoption on two relief forms (convergent concave hillsides and divergent convex). Each hillside was divided in three segments (superior, medium and inferior) so that it roots possible to evaluate the movement of the carbon on the soil and to identify the effect of the handling system.

As the study was accomplished in agricultural properties, the treatments (Table 1) they don't have repetitions. To compensate this fact, and to allow the statistical analysis, samplings were accomplished in nine points of each treatment, being obtained three points in each segment with two repetitions in each point.

Table 1–Summaries of the characteristics of the studied areas:

Management System	Time of use * 1**	2***	I format of the hillside	Slope %	Size Ha	Adopted acronym
Conventional till	40	40	Convex	8	0,30	CTOD
Conventional till	25	25	Concave	8	0,38	CTOC
Minimum till	03	25	Concave	10	0,40	MTOC
No till	02	20	Concave	10	0,35	NTOC
Conventional till	01	-x -	Concave	12	0,60	CTNC
Conventional till	01	20	Convex	8	0,40	CTND
Minimum till	01	-x -	Convex	12	0,35	MTND
Forest	-x -	-x -	Convex	17	0,10	FT

*Time in years
* * Time of current use with this system of preparation of the soil
* * * Time that the area stayed in the type of previous use
* * * *O = old; N = new; D = Convex Divergente; C = Concave Convergent
-x - Under native forest

Characterization of the Organic Matter of the soil:

The analysis of content of organic carbon of the soil was made in samples collected in the depths from 0 to 2,5cm, 2,5 to 7,5cm, 7,5 to 17,5cm.

In these samples the total content of organic carbon was determined (COT) through analysis in a Zhimadzu analyzer of Total Organic Carbon. The carbon fractions was obtained by the method proposed by Cambardella and Elliot (1992) as described by Bayer et.al (2004). The soil samples were dry to the air and drizzled in sieve of mesh 2mm. An aliquot of 20g of soil and 70mL of of sodium hexametaphosfate (5g.L-1) was agitated for 15 hours in horizontal agitator. The obtained suspension was last in sieve of 53µm with aid of a jet of water. The material retained in the sieve it was considered as being the fraction of particulate carbon (COP). This material was dried in greenhouse at 45^{o}C, grinded and had analyzed to obtain the COT. The content of COT associated whit mineral phase was obtained by difference between COP and COT

Evaluation of the aggregation of the soil

The evaluation of the aggregation of the soil was made in the depths 0 to 2,5cm and 2,5 to 7,5cm and 7,5 to 17,5cm as the methodology proposed by CARPENEDO & MIELNICZUK (1990). They were collected indeformed field samples of soil and these samples were manually disaggregated for obtained agregates of inferior size to 9,51mm. For the humid sieving, 50g of dry soil were previously humidified and then added in tubes plastic containing water. The tubes were agitated for two minutes in a rotative agitator of 16rpm. The samples were flowed then for a group of sieves of mesh 4,76, 2,00, 1,00, 0,50 and 0,25 and agitated in buckets with water for 15 minutes. After this procedure, the material retained in the sieves it was passed for cans, dry in greenhouse and weighted to obtain the mass of each fraction. The material that it remained in the bucket, composed of soil and water was passed in a game of sieves of mesh 0,105 mm and 0,053mm, being obtained more three fractions, that were also dry in greenhouse and weighted to obtain the mass.

RESULTS AND DISCUSSION

Among the soil management systems the no till was the system that allowed the best restructuring of the soil, identified through the increase of particulate carbon fraction (COP) in the soil organic matter and the largest stability of the aggregates (Figure 1, Table2).

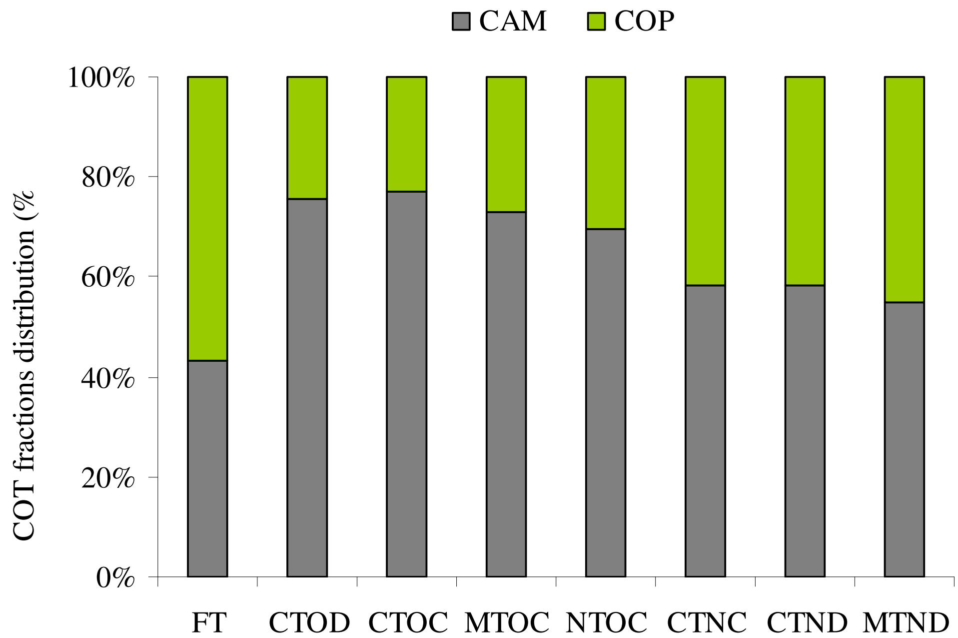

Figure1 – Fractions distribution of the organic carbon for the layer of 0–17,5cm observed in the studied areas in the Cândido Brum watershed.

The organic carbon in the soil is associated with a lot of functions because it is not a homogeneous composition, but a mixture of several fractions in different degradation degrees.

The fraction COP) is the fraction that feeds the organic carbon in the soil, increases in this fraction mean that the system tends to the balance or restructuring. Inversely, very severe reductions mean that the whole stock is being consumed without replacements. In the Figure 1 it possible to identifies that the largest content of COP is in the new areas (CTNC, CTND, MTND). In the old areas, cultivated under conventional till the largest accumulation is observed in the divergent hillside format. Among the management systems that are coming to soil recovery, there is little difference among the values observed in the no till and in the minimum till. This behavior can be attributed as to the handling system as to the geoform of the hillside. Increases in the fraction mineral associated carbon (CAM) can mean increase in the stock of carbon of the soil, once this fraction is the main responsible for the maintenance of the soil carbon. However when this fraction increase in detriment of the fraction COP, indicating that there was not increase absolute, but relative, probably was happening process of soil degradation.

The Table 1 display the values obtained for the relationship MGDw/MGDd. This relationship express how much of the soil aggregates was dispersed when was wetted, so it is a form to express the stability of each one of the aggregates classes. To FT that presented the largest values, this value is not significantly different of the areas CTND and MTND. Among the old cropping areas NTOC presented the best results, not differing from FT except in the last layer. MTOC differed of FT, but it didn't differ significantly of NTOC, and the only one significant difference was in first appraised layer. This can be explained by the accumulation of soil organic matter, that use to be more intense in the first layer in the area under no till, or by the fact of the plowing yet existent in the minimum till, that can be affecting more the first layer. Another factor that can be contributing positively to the increase of the aggregates stability in no till is the application of swine manure in the area. This procedure had been made an only time until the collection of the samples for aggregates analysis. In the new farming areas CTND and MTND presented good results, not differing of FT. These results can be attributed to the high stability of aggregates in soils under pasture in the case of CTND and to the low plowing of the soil in the case of MTND, what must have contributed to maintenance of the aggregates in their correspondent classes.

The positive values observed in the areas of new cropping when compared with the old cropping areas can also be attributed to the content of carbon of these areas, that is larger in the first ones (Figure 1).

Table 5 – MGDw/MGDd of aggregates of the studied areas in Cândido Brum watershed.

Prof (cm)	FT	CTOD	CTOC	MTOC	CTOC	CTNC	CTND	MTND
	--**MGDw/MGDd**--							
0 - 2,5	0,96aA	0,61c	0,65c	0,76b	0,93a	0,75b	0,97a	0,93a
2,5 - 7,5	0,97aA	0,63c	0,58c	0,92a	0,84ab	0,60c	0,94a	0,96a
7,5-17,5	0,92aA	0,54c	0,69bc	0,74b	0,79b	0,66bc	0,89a	0,87a

Averages followed by the same small letter don't differ to each other to 5%

Whatever these results shows that in the appraised areas it is not possible conclude just basing on the different soil management. Is not possible to explain the dynamics of the carbon clearly in the soil, because there are different areas with a similar behavior.

The conventional till indicated the largest losses of carbon generating clear depletion and deposition carbon areas (Figure 2) that were reflected in the aggregates stability.

In the hillsides convex divergent, identified in the legend for the letter D (dealer of water) it is visible that happens intense removal in the superior and medium segments (SS and SM), indicating that this factor influences in the maintenance of the carbon remains the soil. The management soil system effect can be visualized in the comparison among the areas CTOD and CTOC. They both are under conventional till, but the convex area (CTOD) it is tilled in this system along 40 years, while the concave area is by 25 years. The little difference among the contents of carbon indicates the effect of the hillside. This theory can be reinforced to the areas CTNC and CTND, which are under conventional till just by one year and present the same tendency of distribution of the organic carbon.

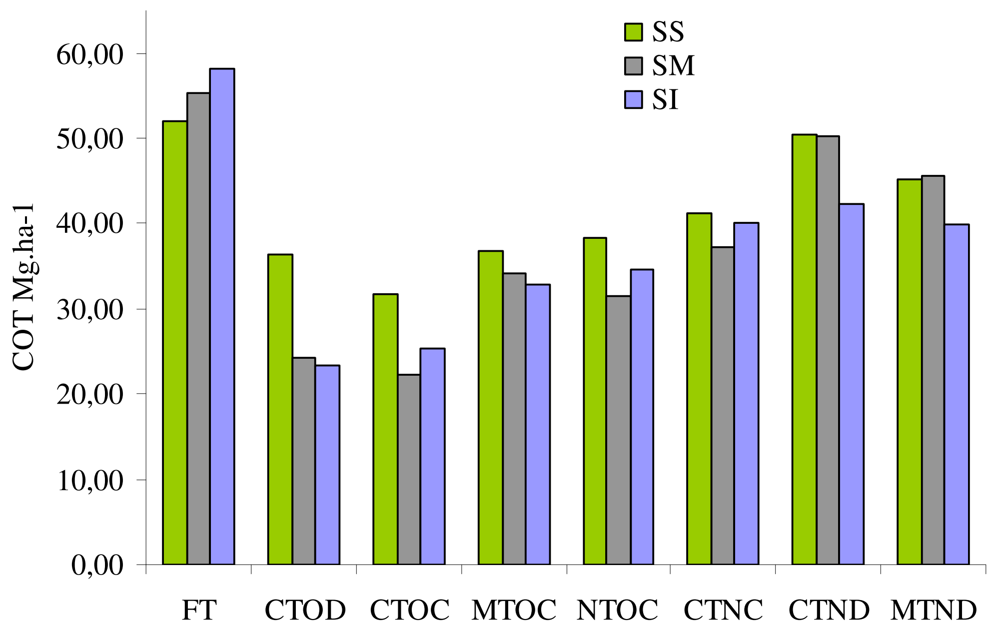

Figure 2–Stock of soil organic carbon for the layer of 0 -17,5cm observed in the studied areas in the Cândido Brum watershed.

Different relief forms if not considered can induce to erroneous evaluations. MOORMAN et.al (2004) evaluated the effects of the cultivation and of the relief in three cultivate watershed being two cultures and similar soil management systems. Although the losses of carbon in the sediments have been coherent with the soil management systems, the smallest losses being observed in the microbacia that used minimum till, the differences found in COT of the soil was more linked with the form of the relief than with the systems of soil management.

The convergent concave hillsides were more sensitive to soil management system, in the degradation as in the recovery of the soils, while the hillsides convex divergent presented larger resilience. Still in the Figure 2, considering that the areas under conventional till are in the direction of the degradation, and that the areas under no till and minimum till are in the direction of the recovery of the soil, is observed a little difference in the content of carbon among the old areas under no till and under conventional till (MTOD and NTOC respectively). These areas were under conventional till before they entering in the conservation systems. The no till system is the best system to accumulates carbon, due to no plowing of the soil and reduction of the erosion, and consequently reducing the carbon exportation. Then it would be waited that the largest earnings of carbon will be in this area. However, there was not significant difference between the stock of carbon of the two systems and this it can be indicating that the format of the hillside influencing the dynamics of the carbon. In the concave hillsides, as in the no till the removal process is more intense, and this does with the two systems are equaled. The Figure 3 presents the correlation analysis among the content of carbon in the different segments of the hillsides and the aggregation of the soil.

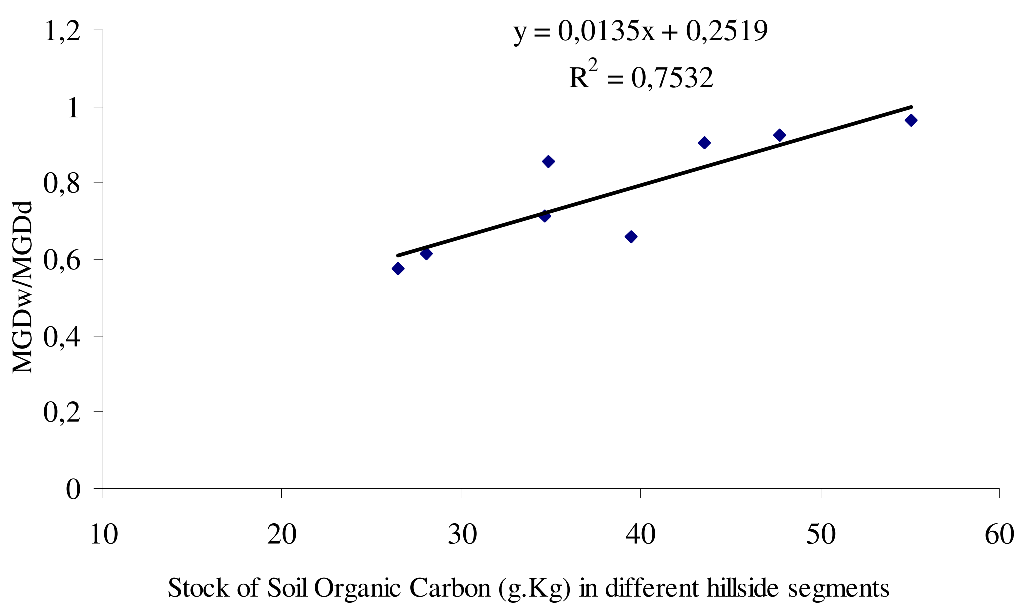

Figure 3 - Correlation Analysis between the content of organic carbon in the different segments of the hillsides and the aggregation of the soil expresses for the relationship MGDw/MGDd .

It is observed that correlation exists among the appraised factors, indicating that the aggregation state depends on the amount of present carbon in the soil, what agrees with results obtained by other authors (RESENDE et al. 1997; LAL et al. 1997, VEZZANI, 2002, CONCEIÇÃO 2002). However it is necessary to remind that inside of a same soil management system the stock of carbon varied in agreement with the format of the hillside and the position in the landscape (superior, medium and inferior segments). In the positions in that format of the hillside favors the permanence of the residue on the soil, and the process of movement of the water in surface and under the surface doesn't happen in an accelerated way, there is more probability of formation of stable aggregates and of superior size classes .

CONCLUSIONS

Among the soil management systems evaluated the no till presented larger efficiency to increase the amount of soil organic carbon and to reduce your removal. The minimum till also presented good acting, but it presented more influences of hillside format, indicating smaller efficiency in retaining the carbon on the hillside.

The obtained results indicate that the format of the hillside should be considered in the adoption of handling systems, especially in the opening of new areas, to avoid the severe degradation or to accelerate the recovery process in areas already degraded.

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