REHABILITATION OF A SECONDARY NETWORK OF FOREST TRAFFIC INFRASTRUCTURE (SKID ROADS – SKID TRAILS)

Muhamed Bajrić, Forestry Faculty, University Sarajevo, B&H, (bajric_muhamed@yahoo.com)
Dževada Sokolović, Forestry Faculty, University Sarajevo, B&H

Abstract: Forest transport infrastructure is the key segment of rational forest resource management. One of its constituent and inseparable segments are skid roads and skid trails whose network density significantly exceeds the primary network, i.e. truck roads. Skid road - skid trail network density in high economic forests of FB&H is most often between 40 and 100 m/ha. Simplified way of construction, non-existence of road construction, objects for surface water drainage as well as significant longitudinal inclination (up to 50%) in which they are constructed, makes them subject to erosion processes. The lack of rehabilitation measures on skid roads - skid trails causes significant damages in post-exploitation period, and very often to the extent that the ones in the following exploitation round are unusable for skidding. Utilization of skid roads - skid trails damaged by erosion processes for forest operations often represents a significant expense. This paper considers rehabilitation measures efficient from the point of remedying erosion processes, and at the same time, acceptable from the point of financial expenditure for forest operations.

Key words: skid roads – skid trails, erosion, rehabilitation measures, rehabilitation costs

INTRODUCTION

Skid roads – trails represent an important segment of the overall network of forest traffic infrastructure, without which forest exploitation in B&H would be unimaginable. Although today’s demands from society towards forestry are different and often with expressed criticism, even when forest communication network is the issue, the need for the construction of primary as well as of secondary network is constantly present. B&H forestry operations very often equal the term of skid road with the term skid trail, which is wrong. According to Šikić and others (1989):

- Skid roads are construction objects where earthworks are present, but the top layer is not constructed:
- Skid trails are temporary construction objects we get by cutting through forest and by frequent movement of tractors along the same trail (“wasteland movement”).

In a large number of cases of construction and exploitation of skid roads – skid trails, comes the erosion process in various shapes and volumes.

Need for intensive construction of skid roads - skid trails has become more expressed at the end of 50’s and early 60’s of the past century, when forest operations in larger volume introduce various types of tractors (mechanization) which, for efficient work, require construction of specific category of forest traffic infrastructure.
One can say that construction of skid roads has three main functions: biological, technical and economic function (Kulušić, 2003). From the biological aspect, construction of skid roads has the objective that the movement of forest mechanization (in skidding phase) and cargo/weight in forest compartment be limited to the lines (for that purpose) and in that way minimize damage to standing, young trees, root system and compaction of productive forest land. From the technical and economic aspects, construction of skid roads has the objective to enable mechanization to easily and quickly move through harvested material, which contributes to savings in labor time, increase of machine productivity and reduction of production costs.

With the construction of skid roads (similar as during truck road construction, but in a lot smaller volume) occurs a kind of aggression on the environment. If this type of forest traffic infrastructure is constructed in accordance with the accepted principles and rules, than those are not considered “an alien body” in a forest ecosystem, but represent one of the links in proper forest management. However, benefits from skid roads - skid trails construction are larger than their harmful impact. But this claim is justified only in cases when, during construction, all norms of forestry profession are completely respected, and, on the other hand, when all requirements regarding environmental protection, which is getting more and more important, are respected to the maximum.

Skid roads construction justification is unquestioning and most often in our forestry does not have adequate alternative. Although cableway is often mentioned as alternative to skid roads construction, in a large number of cases, exploitation of our forests via cableways is not economically justified, which is usually prioritized over ecological factors that are often neglected.

Skid roads represent temporary objects constructed primarily for the exploitation of the main forest resource – wood. Special designs in B&H forestry are not prepared for constructions of skid roads - skid trails, but they are constituent part of Construction designs prepared at the level of individual forest compartments (FB&H Law on Forests, 2002). In our forest operations we do not have specialists who are exclusively designing skid roads - skid trails; these assignments are done by graduated forestry engineers, working in the production preparation sector (designers), with minimum two years of work experience (FB&H Law on Forests, 2002).

Density of skid roads network varies, and above all depends on terrain configuration and management manner. The densest network is required for mountainous areas with expressed terrain configuration where mixed-age is used as the management system. The lowest density of skid roads is required for plain fields. For terrain conditions prevailing in our forests (mountainous areas), as optimal openness with skid roads - skid trails Jelićić (1981, 1988) recommends openness up to 150 m/ha, even to 200 m/ha, when mixed-age forest management is used. Considering that road construction, as well as drainage of objects are not constructed during skid road construction, along with the fact that those are designed with relatively large longitudinal grades/inclinations (up to 50%), although that is not in accordance with technical regulations for construction, it opens up space for the appearance of erosion processes.

The very technique of skid roads construction is rather simple, as it does not require special works regarding structuring of the driving surface. Construction of skid roads is based on breaking through the terrain using construction machinery, in our forest operations usually with stronger dozer machines. The construction of skid roads disturbs the natural stability of surface layers of soil. Also, very often it disturbs the master sub-strate which initiates actions of erosion processes. During construction of skid roads most often one, at a large or smaller scale cuts into the terrain, with damages that inevitably appear during exploitation of the ones, which causes accelerated erosion processes on them.

Constructed skid roads in practice most often do not have a quality solution for the drainage of surface water. For surface water drainage from skid roads, it is recommended to construct lateral grade/inclination of 3 – 5% in the direction of the slope (Jelićić, 1985), which, according to present experiences from practice, is not largely done. In cases when surface water drainage is done in this way, the effect of this solution is lost very quickly with rut formation, due to a frequent passage of tractors, whereby creating conditions to redirect flows, which leads to the appearance of erosion.
processes, and in extreme cases skid roads become torrential streams. Rut formation also has other negative consequences, “As a consequence of ruts, comes decrease in aeration of the soil, which disables the growth of roots and decreases vegetation cover (Byblyuk et al, 2010).”

It is not rare that as a consequence of forest resource exploitation there is soil erosion whereby dimming water courses, and also, water sources which in a large number of cases represent basis for potable water supply for population.

Although positive legal regulations regulate the obligation to rehabilitate skid roads- skid trails after exploitation (Rule book on volume of measures on establishment and maintenance of Forest order and the way of enforcement, 2002), up to date experiences in forest operations mainly show that those are not followed. Considering the expressed danger of negative action of erosion processes on the secondary network, facilitation of rehabilitation measures imposes as the only efficient solution in the prevention of erosion processes. Maintaining a satisfactory degree of coverage (degree of covering ground with tree crowns/tops), as well as the existence of grass vegetation, has a positive effect on the appearance of erosion processes. Forest vegetation provides the best soil protection from accelerated erosion (Prpić et al, 2005).

The selection of an efficient rehabilitation measure besides efficiency in the prevention of erosion processes should also be based on the reality of facilitation of those, above all, from the economic standpoint by selecting the rehabilitation methods that would be acceptable for forest operations as well, which this paper deals with.

**WORK METHODS**

Within two forest sections where forest exploitation works are completed, we set-up experimental plots. In one of the selected forest sections (section 28, MU “Gornja Rakitnica”) we performed an experiment with grassing over as skid road-skid trail rehabilitation measure with two experimental plots. In both cases we talk about new-constructed skid roads. Inclination of the skid road was approx. 12%. Grassing over was done immediately after exploitation and on both plots simultaneously. Dimensions of experimental plots are 20x3 m (60 m²). On one of the experimental plots we used seed from a nursery (English ryegrass (Lolium perenne L.) 60%, red fescue (Festucarubra L.) 30% and red fescue – echo (Festucarubra L.) 10%), while on the other we used “Hay Flowers” (remains of the seed of different mountainous grass from hay from a narrow location of the research).

Both plots were divided into two equal areas of 10x3 m dimensions (30 m²). On one part of the plot we only removed leaf litter from the surface of the skid road- skid trail, while on other part we additionally loosened the soil using a metal rake for establishing an easier contact between the seed and the soil. After preparing the soil, we seeded the experimental plots, one with seed from a nursery, and the other with “Hay Flowers”.

The effect of the conducted grassing over method shall be evaluated by visual inspection of coverage of the surface on which the treatment was conducted.

In another forest section (section 9, MU “Vogošća Bulozi”), after performed exploitation we selected a section of skid road with somewhat larger longitudinal grade/inclination (approx. 35%). As rehabilitation measure we chose construction of lateral ditches in distances of 25 m.

In order to, more precisely, define the effect of lateral ditches, we shall perform a survey in specific time periods, marked as survey phases. The first phase represents survey immediately after construction of the skid road, the second one immediately after exploitation, and the third, fourth and fifth ones in equal time spans of post-exploitation period.

In order to determine the true effect of setting up lateral ditches on skid roads, it shall not be constructed immediately after the exploitation phase (phase 2). Namely, the construction of lateral canals is planned after phase III of gathering field data, whereby we want to determine dynamics in the development of erosion processes without facilitating rehabilitation measures, that is in the first three survey phases. After phase III, we will construct lateral canals and perform survey on those during regular surveys for phases IV and V. Based on gained results we will compare development of erosion processes before and after the performed rehabilitation measure, as well as determine the efficiency of the performed rehabili-
tation measure (based on the surveyed status on profiles in the period between surveys on phases 3, 4 and 5).

Digging/excavation of lateral ditches shall be done at an angle of approximately 35°, while the width at the bottom of the canal is planned to be approx. 40 cm. During execution of works on digging/excavation of lateral ditch, material excavated shall be placed on the lower side of the canal to prevent eventual water overflow over canal.

Schematic depiction of proper construction of lateral ditch is presented in Image 1.

It is planned to place a total of three canals on the experimental plot in the length of approximately 50 m, whereby we want surface water that flows along the formed ruts on the skid road to be redirected down the slope.

The control of dynamics in the development of erosion processes shall be done in the following manner: through 5 survey phases on the experimental plot, every 5 m we will record the lateral profile, where at every 20 cm, we will measure the perpendicular distance from the horizontal position of the bar to the terrain. Based on recorded values, for all profiles we will calculate areas for taken away – brought material, and on the basis of profile areas and distances between individual profiles, we will calculate the volume of taken away and brought material. As the basis for the calculation of areas, we will use the first survey phase (immediately after skid road construction).

The areas for II, III, IV and V survey phase are gained in relation to the terrain line of lateral ditches from the first survey phase, and that for the calculation of areas of brought material as difference between the terrain line of the first and other survey phases above gained terrain line for the first phase, and similarly for the taken away material, with the difference that the areas below are considered.

**RESEARCH RESULTS**

a) Grassing over as the rehabilitation measure

Conducting of the treatment primarily had the objective to show the possibility of application of grassing over as a measure to combat erosion, i.e. to determine whether after treating the skid road with some grass mixtures one can achieve satisfactory grass coverage, which would have significant effect in the prevention of erosion processes. Also,
with a planned use of different type of grass seed we wanted to determine which one achieves larger grass coverage, and what type can be recommended to forest operations during the execution of rehabilitation measures.

The observation period was approximately 15 months. The results of the conducted treatment with “Hay Flowers” seed and nursery seed are visible in photos 2 and 3.

The success of conducted rehabilitation measure on the surface treated with “Hay Flowers” for both plots can be evaluated as satisfactory (Photo 2). Although, it is necessary to emphasize, somewhat larger coverage was on a plot where, besides removal of leaf litter, we have additionally loosened the soil. Through visual inspection of the success of the conducted rehabilitation measure, on one half of the plot where leaf litter was removed, the coverage was approx. 70 – 80%, while on the half of the plot where we have also loosen the soil, the coverage was approx. 80- 90%.

Unlike in the previous case where we could conclude that success of the treatment was satisfactory, in grassing over with nursery seed the same cannot be concluded (Photo 3). As in the previous case, we have visually inspected grass coverage, that is success of the treatment. Also, in this case we can conclude that part of the plot where, besides leaf litter removal, we have loosened the soil, success of the treatment was somewhat larger. In the part of the plot where we only removed leaf litter, success of the treatment was between 30 and 40%, while in the part of the plot where we additionally loosened soil, success of the treatment was approximately 50% of soil coverage.
b) Lateral ditches as the rehabilitation measure

The construction of lateral canals was conducted in the part of the skid road with an average longitudinal grade/inclination of 34.1%. With the fact that inclination on the treated part of the skid road was relatively large, the part of the skid road which was not treated with this rehabilitation measure, in which the experimental plot continues in the length of approx. 100 m, also was sloped and had an inclination between 15 and 20%. In addition to the above, it is significant to emphasize that there was a water way on the treated skid road (appearing periodically throughout the year) which appeared by cutting the sub-surface flow as a consequence of skid road construction.

The way in which cutting of lateral canals was done on the skid road is visible in Photo 4.

As one could presume, the efficiency of a rehabilitation measure executed in this way was completely satisfactory regarding longitudinal removal/taking away of material from the skid road.

However, at the calculation of quantity of brought material at specific profiles, this effect cannot be determined because in case of brought material, it mostly comes from eroded material appeared as a consequence of soil dispersal from cut-in portion of the terrain on the skid road.

The quantities of brought/taken away material, as well as the effect of setting-up lateral canals on the skid road are visible in Table 1.

The values of quantities of brought material obtained for specific survey phases (Ph II – Ph V) clearly speak of the efficiency of this method

<table>
<thead>
<tr>
<th>Length (m)</th>
<th>Volume of taken away material (PhII - PhI)* (m³)</th>
<th>Volume of brought material (PhII - PhI)* (m³)</th>
<th>Volume of taken away material (PhIII-PhI) (m³)</th>
<th>Volume of brought material (PhIII-PhI) (m³)</th>
<th>Volume of taken away material (PhIV-PhI) (m³)</th>
<th>Volume of brought material (PhIV-PhI) (m³)</th>
<th>Volume of taken away material (PhV-PhI) (m³)</th>
<th>Volume of brought material (PhV-PhI) (m³)</th>
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<td>14,75</td>
<td>3,75</td>
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</table>

PhII-PhI – represents the difference in the quantity of taken away/brought material for individual survey phases
of skid road rehabilitation. Marks PhI, PhII, PhIII, PhIV and PhV mark survey phases on lateral profiles. The final values of quantities of taken away/brought material were obtained as differences of the certain survey phase and initial state (PhI). As it is visible in the tabular overview, in the period while the rehabilitation was not done yet (survey Phases II and III), there was an increase in the volume of taken away material from the skid road. In the period after the completed survey of Phase III (after which lateral ditches for surface water drainage were constructed), and until the end of the conducted research (Ph IV and Ph V), it is obvious that there was a decrease in total volume of taken away material, that is, erosion processes stopped in taking away material from skid road. Here it is important to mention that the decrease in the area of certain profiles is not the result of brought material onto the skid road as consequence of longitudinal transport, but appears as a consequence of material dispersal from the slope of cut-in that continues even after this rehabilitation measure was executed. Unlike the quantity of taken away material, which appears mainly as a consequence of longitudinal transport, the quantity of brought material on the skid road during overall research period was constantly increasing, which is the result of constant dispersal of material from the cut-in portion of the skid road. The dispersal of the material from the cut-in portion of the skid road shall continue until the slope is formed on which the material from the cut-in shall reach such inclination when the balanced state will be established, i.e. the dispersal shall stop.

**DISCUSSION**

Up to date experiences in managing forest resources in B&H show that rehabilitation measures on skid roads – skid trails are mainly left out. A confirmation of this claim are previous researches in which 25 forest sections were covered in which there was no trace of rehabilitation (Bajrić, 2012; Bajrić et al, 2013; Vukojičić, 2014; Musić, 2015; Hajdarević, 2015). Positive legal regulations through by-laws prescribe the obligation of rehabilitation of a secondary network after the completion of works on forest exploitation (Rule book on the volume of measures on the establishment and maintenance of Forest order and the way of enforcement, 2002), which in practice is not applied.

Through conducted experimental research in this paper it is proven that rehabilitation measures that were conducted have good results, and their application for forest operations is justified, as from the point of efficiency, as well from the point of financial investments that for application of these methods are relatively low (Bajrić, 2012).

Grassing over measures have a particularly good effect in the prevention of appearance of initial phases of erosion from rain drop impacts, because there is abundant grass cover protecting the soil from erosion. Application of the grassing over method provides good results which coincides with the researches and conclusions of other authors that deal with similar issues. Primary objective of skid road rehabilitation is to regain natural drainage on slopes, whereby preventing erosion (Curran & Dykstra, 1997). Skid road rehabilitation after wood skidding is one of the most important issues in environment protection (Lotfalian & Bahmani, 2011). Establishing vegetation cover on skid roads exposed to erosion processes prevents sedimentation and washing out of nutrients (Brooks et al, 2011). An increase in the coverage of skid roads with vegetation increases the degree of protection from erosion processes (Wade et al, 2010).

On an issue of construction of lateral ditches as rehabilitation measure, there is a satisfactory effect. After the executed rehabilitation measure (construction of lateral ditches), taking away of material from skid roads stopped, visible in Table 1. This measure did not have an impact on brought material, which was not a result of longitudinal transport of material, which originates from the slopes of the cut-ins of the skid road. Positive experiences in the application of lateral canals as a rehabilitation measure in his works are expressed by Jelićić (1981, 1988). In addition, as an efficient measure of protecting skid roads from erosion processes, the construction of lateral ditches on suitable distances we can find in “Virginia’s Forestry Best management Practices...”, 2011 and other similar manuals covering best forest management practices (BMP, 2002, 2004, 2009).
CONCLUSIONS

• In grassing over as the rehabilitation measure for skid roads, particularly efficient was the application of seed from natural grass—“Hay Flowers”. The conducted rehabilitation has a good effect even in the case when only leaf litter is removed, after which grass coverage amounts to 70 – 80%. Better results were achieved when, besides the removal of leaf litter, we loosed the soil with a metal rake. In this case the coverage was approx. 80 – 90%, and we can conclude that grassing over with “Hay Flowers” is a completely justified method of skid road rehabilitation, considering that it achieved satisfactory coverage which has crucial effects in minimizing erosion processes.

• The application of nursery seed did not provide satisfactory results, considering that the coverage in the case when only removal of leaf litter was done amounted to 30 – 40%, while the same in case of additional soil loosening to 40 – 50%, and the same also cannot be considered satisfactory.

• The mentioned differences in grass vegetation coverage for cases of grassing over with “Hay Flowers” and nursery seed can be explained by a better adaptability of “Hay Flowers” seed to local climate conditions, unlike nursery seed that is harder to adapt to these local climate conditions (altitude above sea level of experimental plots was approx. 1.400 m), although the so-called “mountain seed” was used.

• The use of lateral canals, as the way to prevent erosion processes on skid roads, showed as a very efficient measure. The result of conducted rehabilitation is stopping the process of taking away the material from specific profiles reflected through gained values of volume of taken away material for specific survey phases (PhII – PhI = 13.60 m³, PhIII – PhI = 14.87 m³, PhIV – PhI = 14.73 m³ and PhV – PhI = 14.24 m³), where, obviously there was a complete stopping of longitudinal taking away of material process. The obtained results clearly tell us about achieving the set objective, that is, stopping of erosion processes on the skid road through conducted rehabilitation.

• Unlike taken away material from skid roads, in the case of construction of lateral ditches, in brought material we see a constant increase in volume per observation periods (PhII – PhI = 3.06 m³, PhIII – PhI = 3.46 m³, PhIV – PhI = 3.75 m³ and PhV – PhI = 4.52 m³), that is, this rehabilitation measure did not have an impact. However, the increase is not the result of longitudinal bringing of material, but in this case the dominant role has the dispersal of material from slopes of cut-ins on profiles. The above points out that during skid road construction, we need to pay more attention to the construction of slopes of cut-ins (appropriate inclination), and points to the need to conduct appropriate rehabilitation measures on it.

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