**Excerpt from draft soils analysis for the Stella Vegetation Project, High Cascades Ranger District, Rogue River-Siskiyou NF. Joni Brazier, 3/27/2020**

**Ground-based Mechanized Tethered/Winch-Assisted Systems on Steep Slopes**

Advances in ground-based harvest equipment technology are making it more possible to safely operate mechanized felling, pre-bunching, and yarding equipment on steeper slopes (greater than 35%), such as through using self-leveling feller-bunchers or tethered harvester-forwarder systems. Industry has been encouraging these developments to increase operator safety as well as increase production and improve economic feasibility, due to the high costs of conventional cable and helicopter systems (Flint and Kellogg 2013, Visser et al. 2013, Acuna et al. 2011). A study in the Coast Range of Oregon looking at the productivity and cost of six different steep slope harvesting systems found that all steep terrain harvester-forwarder systems had the lowest overall harvesting costs, but also that utilizing a specialized steep terrain harvester which processed and pre-bunched for a cable yarding system, caused an increase in productivity of 79% and a reduction in cost of 58% for the cable yarder (Flint and Kellogg 2013). Similarly, a research trial in Australia found that utilizing a self-leveling feller-buncher to fell and pre-bunch stems for cable yarding on slopes between 36-47%, on dry, sedimentary-based soils with good traction, increased productivity of the cable logging operation (Acuna et al. 2011). While both studies resulted in positive outcomes for economics, neither study examined effects of these systems to soil.

Relatively little research has been done to date, to determine the disturbance effects to soil productivity when utilizing steep-slope harvesting systems. Some reviews of the potential slope limitations of various ground-based harvest equipment discuss the safe operating range as related to soil bearing capacity and percent slope (Visser and Stampfer 2015, Visser et al. 2013). Soil bearing capacity focuses on the maximum average contact pressure between the load (in this case, the machine), and the soil which should not produce shear failure. However, this should not be equated to the contact pressure that would result in detrimental soil productivity impacts; it is expected that other detrimental effects would likely result in the soil before reaching the point of vehicle slippage and shear failure. Based on their review, Visser and Stampfer (2015) provide guidelines for slope limits for different kinds of ground-based equipment, but these guidelines focus on safety, not impacts to soils, and they recognize that few studies have been done to quantify disturbance. In their economic study, Flint and Kellogg (2013) recognized the importance of considering the potential effects of soil disturbance, not just the economics, of steep terrain ground-based operations.

A recent study in the western Oregon coast range (Zamora-Cristales et al. 2014) evaluated the effects of two systems, a harvester-cut, cable-yarded unit and a harvester-cut, forwarder-yarded unit, on mineral soil exposure and soil strength on slopes averaging 65% and 58%, respectively. Soils were dominated by very gravelly loams. Operations occurred with soil moistures ranging from 30 to 39% (harvester-cable) and 30-36% (harvester-forwarder). The harvester-forwarder system resulted in two, downhill passes on designated skid trails; the harvester-cable system resulted in one, downhill pass on designated skid trails, with logs being cabled uphill. Steep trails represented 15% of the area in the harvester-cable unit, and 10% of the area in the harvester-forwarder unit. Spacing of trails ranged from 18 to 24 m (approx. 60 to 80 ft.) apart. On harvester-forwarder, 7% of the sample points, and 3% of the sample points in harvester-cable, had exposed mineral soil; the statistical analysis of the data generally confirmed that each harvest unit remained below 10% exposed soil. Regarding soil strength, there was no apparent relationship between changes to soil strength and the percent slope, for either system. An evaluation of the relationship between soil strength and slash showed that operating on slash mats resulted in less increase in soil strength over adjacent undisturbed soil, than operating on no slash. When considering the effects of soil strength on forest site productivity, the soil strength on the 2-pass harvester-forwarder unit trails averaged about 2,770 kPa, whereas the single-pass harvester-cable unit trails averaged about 2,096 kPa. Soil strength levels of about 2,500 kPa or higher are considered to start inhibiting vegetation growth on a variety of soils (Page-Dumroese et al. 2006, cited in Zamora-Cristales et al. 2014). These impacts were only seen within the designated trails, which did not exceed 15% of the area in both units. Dry season operations, only 1 to 2 vehicle passes on trails, and an operating system that added slash to the trails and generally limited ground disturbance, as well as skilled operators, are considered factors that contributed to the results of this study.

On the Fremont-Winema National Forest in south-central Oregon, soil disturbance monitoring was completed on a timber sale unit which was thinned in the summer of 2016 utilizing a tethered harvester and forwarder on wheel tracks (Rone 2017). Average slopes in the unit were approximately 20 to 60%, with soils consisting of coarse pumice which were operated on in dry soil moisture conditions. Shortly after harvest completion, soil disturbance monitoring transects identified 9% and 6% in disturbance class 2 and 3, respectively, which in these soil types the soil scientist considers detrimental soil disturbance (G. Rone, pers. comm.). Initial direct soil disturbance was dominated by soil displacement over compaction, which is related to the coarse, non-cohesive properties of the pumice soil in the unit. Some other operational concerns that were observed were machine side tracking and turning impacts, the disintegration of slash mats, and converging and side-by-side skid trails. Monitoring identified multiple recommendations to help shape project design criteria and mitigations for future steep slope operations, as well as the need to monitor again after a wet season.

The Stella project is focusing on allowing the potential use of tethered/winch-assisted harvest equipment on slopes greater than 35% if appropriate equipment and methods are available at the time of implementation. Specifically designed project design criteria and mitigations have been developed to guide the use of this method and assure activities meet soil resource standards and guidelines (refer to Best Management Practices/Mitigation Measures/Project Design Criteria section in this report).