Bark thickness, bark volume and bark proportion of pine logs

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In order to tackle climate change and mitigate global warming, forests play an important role: (i) through carbon sequestration and (ii) through reducing carbon emissions by providing both wood products and bioenergy to store carbon and as a substitute for other emission-intensive products and fossil fuel energy (Xu et al. 2017). Nevertheless, forests are affected by climate change, and, thus, “policies and plans must account for the trade-offs between forests’ capacity to store carbon, adapt to climate change and yield wood products and other ecosystem services” (Fares et al. 2015). Against this background, the concept of bioeconomy plays a very important role and influences the management of forests. Especially the so-called wood-based bioeconomy is mainly driven by wood from forests as round timber, pulpwood and forest residues (Hagemann et al. 2016). More recently, besides timber, new biomaterials made from wood and bark are getting more and more important for climate change mitigation, with steadily growing market segments. Bark is very promising as its unique chemical composition allows to get many different products (e.g. tannin and betulin) from which various materials can be produced (Bauhus et al. 2017; Jansone et al. 2017).

When collecting all tree compartments (including bark, branches, foliage) maximum biomass harvest is reached. Still, such whole tree harvest is connected with an increased risk of nutrient depletion, as nutrient removal is considerably increased in comparison to more moderate harvesting scenarios (Ghaffariyan et al. 2017; Huber et al. 2017; Weigel et al. 2017).

On the one hand, the demand of forest-based materials (e.g. timber, bark) are increasing, but, on the other hand harvesting whole trees (including bark, branches and foliage) could have a negative long-term impact on forest productivity. As bark contains large amount of nutrients (especially N, P and K) (Yan et al. 2017) it is of importance to quantify the amount of bark (and, thus, nutrient removals) which is removed from forest when harvesting trees to ensure sustainable forest management. However, it is also from importance for biorefineries to know the amount of bark they can expect to produce environmentally friendly products and materials.

To the best of our knowledge, most studies dealing with bark content of timber measured bark thickness which can be further used to deduce merchantable timber volume (e.g. Stängle et al. 2016; Jankovský et al. 2019). Nevertheless, to have more accurate results, not only bark thickness is of importance but particularly bark volume and bark mass. None of the found studies determined the bark volume with calibratable exactitude, a requirement to make use of that parameter in sales and marketing processes and for billing purposes. Thus, the objective of the research is:

- to determine bark volume with high accuracy,
- to estimate by regression the relationship between exogenous variables (e.g. tree height, tree age, diameter at breast height) and bark volume,
- to estimate by regression the relationships between bark thickness and bark volume

For the analysis *Pinus sylvestris* logs –as the most widely distributes pine species in the world– will be measured at the host institution (INRAe Nancy, France) with different techniques to evaluate the accuracy and applicability of these measuring methods. In a first step, the logs will therefore be scanned nondestructively with X-ray in order to measure bark thickness and bark volume at very high resolution and degree of accuracy. It is proven, that with such computer tomography (CT) techniques, automated bark detection can be performed for softwood species (Stängle et al. 2016). In a second step, bark thickness at predefined measurement points as well as bark volume shall be assessed a) visually on the screen and b) automatically with algorithms. Additionally, it is planned to measure the diameter (over bark) of the 3-m-long logs at the predefined points with a caliper. Afterwards, the logs will be debarked manually with a bark spud before being measured again at the same measuring points. Thus, bark thickness can be deduced from the measurement with and without bark. Following that, bark volume shall be calculated from log volume in bark minus log volume without bark, calculated with well-known equations (e.g. Smalian’s formula).

Finally statistical analysis will be performed with the two dataset (manual and CT).