Removals, trees/acre

$$RemovalsST = RemovalsCT + RemovalsSLT \quad (1)$$

$$RemovalsALT = RemovalsSLT + RemovalsLLT \quad (2)$$

$$Removals = RemovalsCT + RemovalsSLT + RemovalsLLT \quad (3)$$

CT – Chip Trees

SLT – Small Log Trees (<=80 ft3)

LLT – Large Log Trees (>80 ft3)

SL – Small Trees (<=80 ft3)

ALT – All Log Trees

Volume Per Acre, ft3/acre

$$VolPerAcreCT = RemovalsCT \times TreeVolCT \quad (4)$$

$$VolPerAcreSLT = RemovalsSLT \times TreeVolSLT \quad (5)$$

$$VolPerAcreLLT = RemovalsLLT \times TreeVolLLT \quad (6)$$

$$VolPerAcreST = VolPerAcreCT \times TreeVolSLT \quad (7)$$

$$VolPerAcreALT = VolPerAcreSLT \times TreeVolLLT \quad (8)$$

$$VolPerAcre = VolPerAcreCT + VolPerAcreSLT \times TreeVolLLT \quad (9)$$

Tree Volume, ft3/tree

$$TreeVolST = \frac{VolPerAcreST}{RemovalsST} \quad (10)$$

$$TreeVolALT = \frac{VolPerAcreALT}{RemovalsALT} \quad (11)$$

$$TreeVolST = \frac{VolPerAcre}{Removals} \quad (12)$$

Other Assumptions

$$MaxManualTreeVol, ft3 = 150 \quad (13)$$

$$MaxMechTreeVol, ft3 = 80 \quad (14)$$

$$MoistureContentFraction, wet\ basis = 0.50 \quad (15)$$

$$LogLength, ft = 32 \quad (16)$$

$$LoadWeight, green\ tons\ (logs) = 25 \quad (17)$$

$$LoadWeight, green\ tons\ (chips) = 25 \quad (18)$$

$$CTLTrailSpacing, ft = 50 \quad (19)$$

$$HardwoodCostPremium, fraction = 0.20 \quad (20)$$

$$ResidueRecoveryFraction\ for\ WT\ systems = 0.80 \quad (21)$$

$$ResidueRecoveryFraction\ for\ CTL = 0.50 \quad (22)$$

Calculated Intermediates

DBH

DBH – Diameter at Breast Height, in

$$DBHCT = \sqrt{\frac{TreeVolCT + 3.675}{0.216}} \quad (23)$$

$$DBHSLT = \sqrt{\frac{TreeVolSL + 3.675}{0.216}} \quad (24)$$

$$DBHLLT = \sqrt{\frac{TreeVolLLT + 3.675}{0.216}} \quad (25)$$

$$DBHST = \sqrt{\frac{RemovalsCT \times DBHCT^2 + RemovalsSLT \times DBHSLT^2}{RemovalsST}} \quad (26)$$

$$DBHALT = \sqrt{\frac{RemovalsSLT \times DBHSLT^2 + RemovalsLLT \times DBHLLT^2}{RemovalsALT}} \quad (27)$$

$$DBH = \sqrt{\frac{RemovalsCT \times DBHCT^2 + RemovalsALT \times DBHALT^2}{Removals}} \quad (28)$$

Tree Height

$$HeightCT = -20 + 24 \times \sqrt{DBHCT} \quad (29)$$

$$HeightSLT == -20 + 24 \times \sqrt{DBHSLT} \quad (30)$$

$$HeightLLT == -20 + 24 \times \sqrt{DBHLLT} \quad (31)$$

$$HeightST = \frac{RemovalsCT \times HeightCT + RemovalsSLT \times HeightSLT}{RemovalsST} \quad (32)$$

$$HeightALT = \frac{RemovalsSLT \times HeightSLT + RemovalsLLT \times HeightLLT}{RemovalsALT} \quad (33)$$

$$Height = \frac{RemovalsCT \times HeightCT + RemovalsALT \times HeightALT}{Removals} \quad (34)$$

Wood Density

If the wood density for chip trees, small log trees or large log trees is not specified by users, then it is 50 lb/ft3 by default.

$$WoodDensityST = \frac{WoodDensityCT \times VolPerAcreCT + WoodDensitySLT \times VolPerAcreSLT}{VolPerAcreST} \quad (35)$$

$$WoodDensityALT = \frac{WoodDensitySLT \times VolPerAcreSLT + WoodDensityLLT \times VolPerAcreLLT}{VolPerAcreALT} \quad (36)$$

$$WoodDensity = \frac{WoodDensityCT \times VolPerAcreCT + WoodDensityALT \times VolPerAcreALT}{VolPerAcre} \quad (37)$$

Hardwood Fraction

If the hardwood fraction for chip trees, small log trees or large log trees is not specified by users, then it is 0 by default.

$$HdwdFractionST = \frac{HdwdFractionCT \times VolPerAcreCT + HdwdFractionSLT \times VolPerAcreSLT}{VolPerAcreST} \quad (38)$$

$$HdwdFractionALT = \frac{HdwdFractionSLT \times VolPerAcreSLT + HdwdFractionLLT \times VolPerAcreLLT}{VolPerAcreALT} \quad (39)$$

$$HdwdFraction = \frac{HdwdFractionCT \times VolPerAcreCT + HdwdFractionALT \times VolPerAcreALT}{VolPerAcre} \quad (40)$$

Butt Diameter

$$ButtDiamSLT = DBHSLT + 3 \quad (41)$$

$$ButtDiamST = DBHST + 3 \quad (42)$$

Logs Per Tree

Logs per chip tree was assumed as 1.

$$LogsPerTreeCT = 1 \quad (43)$$

$$LogsPerTreeSLT = -0.43 + 0.678 \times \sqrt{DBHSLT} \quad (44)$$

$$LogsPerTreeLLT = -0.43 + 0.678 \times \sqrt{DBHLLT} \quad (45)$$

$$LogsPerTreeST = \frac{LogsPerTreeCT \times RemovalsCT + LogsPerTreeSLT \times RemovalsSLT}{RemovalsST} \quad (46)$$

$$LogsPerTreeALT = \frac{LogsPerTreeSLT \times RemovalsSLT + LogsPerTreeLLT \times RemovalsLLT}{RemovalsALT} \quad (47)$$

$$LogsPerTree = \frac{LogsPerTreeCT \times RemovalsCT + LogsPerTreeALT \times RemovalsALT}{Removals} \quad (48)$$

Log Volume

$$LogVolST = \frac{TreeVolST}{LogsPerTreeST} \quad (49)$$

$$LogVolALT = \frac{TreeVolALT}{LogsPerTreeALT} \quad (50)$$

$$LogVol = \frac{TreeVol}{LogsPerTree} \quad (51)$$

CTL Logs Per Tree

The minimum for CTLLogsPerTree is 1.

$$CTLLogsPerTreeCT = 2 \times (-0.43 + 0.678 \times \sqrt{DBHCT}) \quad (52)$$

$$CTLLogsPerTree = 2 \times (-0.43 + 0.678 \times \sqrt{DBHST}) \quad (53)$$

CTL Log Volume

$$CTLLogVolCT = \frac{TreeVolCT}{CTLLogPerTreeCT} \quad (54)$$

$$CTLLogVol = \frac{TreeVolST}{CTLLogsPerTree} \quad (55)$$

BFperCF

$$BFperCF = 5 \quad (56)$$

Bole Weight

$$BoleWtCT = \frac{WoodDensityCT \times VolPerAcreCT}{2000} \quad (57)$$

$$BoleWtSLT = \frac{WoodDensitySLT \times VolPerAcreSLT}{2000} \quad (58)$$

$$BoleWtLLT = \frac{WoodDensityLLT \times VolPerAcreLLT}{2000} \quad (59)$$

$$BoleWtST = BoleWtCT + BoleWtSLT \quad (60)$$

$$BoleWtALT = BoleWtSLT + BoleWtLLT \quad (61)$$

$$BoleWt = BoleWtCT + BoleWtALT \quad (62)$$

Residue Weight

RF – Residue Fraction

$$ResidueCT = UserSpecRFCT \times BoleWtCT \quad (63)$$

$$ResidueSLT = UserSpecRFSLT \times BoleWtSLT \quad (64)$$

$$ResidueLLT = UserSpecRFLLT \times BoleWtLLT \quad (65)$$

$$ResidueST = ResidueCT \times ResidueSLT \quad (66)$$

$$ResidueALT = ResidueSLT \times ResidueLLT \quad (67)$$

$$Residue = ResidueCT \times ResidueALT \quad (68)$$

Manual Machine Size

The maximum of ManualMachineSize is 1.

$$ManualMachineSizeALT = \frac{TreeVolALT}{MaxManualTreeVol} \quad (69)$$

$$ManualMachineSize = \frac{TreeVol}{MaxManualTreeVol} \quad (70)$$

Mechanized Machine Size

The maximum of MechMachineSize is 1.

$$MechMachineSize = \frac{TreeVolST}{MaxMechTreeVol} \quad (71)$$

Chipper Size

The maximum of ChipperSize is 1.

$$ChipperSize = \frac{TreeVolCT}{MaxMechTreeVol} \quad (72)$$

NonSelfLevelCabDummy

$$NonSelfLevelCabDummy_{slope<15} = 1 \quad (73)$$

$$NonSelfLevelCabDummy_{15<slope<35} = 1.75 - 0.05 \times Slope \quad (74)$$

$$NonSelfLevelCabDummy_{slope>35} = 0 \quad (75)$$

CSlopeFB&Harv (Mellgren 90)

$$CSlopeFB_{Harv} = 0.00015 \times Slope^2 + 0.00359 \times NonSelfLevelCabDummy \times Slope \quad (76)$$

CRemovalsFB&Harv (Mellgren 90)

$$CRemovalsFB_{Harv} = 0.66 - 0.001193 \times RemovalsST \times 2.47 + 5.357 \times 10^{-7} \times (RemovalsST \times 2.47)^2 \quad (77)$$

CSlopeSkidForwLoadSize (Mellgren 90)

$$CSlopeForwLoadSize = 1 - 0.000127 \times Slope^2 \quad (78)$$

Chardwood

$$CHardwoodCT = 1 + HdwdCostPremium \times HdwdFractionCT \quad (79)$$

$$CHardwoodSLT = 1 + HdwdCostPremium \times HdwdFractionSLT \quad (80)$$

$$CHardwoodLLT = 1 + HdwdCostPremium \times HdwdFractionLLT \quad (81)$$

$$CHardwoodST = 1 + HdwdCostPremium \times HdwdFractionST \quad (82)$$

$$CHardwoodALT = 1 + HdwdCostPremium \times HdwdFractionALT \quad (83)$$

$$CHardwood = 1 + HdwdCostPremium \times HdwdFraction \quad (84)$$

System Product Summary

Amounts Recovered Per Acre

ResidueRecoveredPrimary – WT residue recovered as part of primary product, GT/ac

ResidueRecoveredOptional – Optional residue recovered, GT/ac

$$BoleVolCCF = \frac{VolPerAcre}{100} \quad (85)$$

$$ResidueRecoveredPrimary = ResidueRecovFracWT \times ResidueCT \quad (86)$$

$$PrimaryProduct = BoleWt + ResidueRecoveredPrimary \quad (87)$$

$$ResidueRecoveredOptional = ResidueRecovFracWT \times (ResidueSLT + ResidueLLT) \quad (88)$$

$$TotalPrimaryAndOptional = PrimaryProduct + ResidueRecoveredOptional \quad (89)$$

Amounts Unrecovered and Left within the Stand Per Acre

GroundFuel – Activity fuels (residues) on the ground, GT/ac

$$GroundFuel = ResidueLLT + ResidueST \times (1 - ResidueRecovFracWT) \quad (90)$$

Amounts Unrecovered and Left at the Landing

PiledFuel – Piled activity fuels (residues), GT/ac

$$PiledFuel = ResidueSLT \times ResidueRecovFracWT \quad (91)$$

TotalResidues

$$TotalResidues = ResidueRecoveredPrimary + ResidueRecoveredOptional + ResidueUncutTrees + GroundFuel + PiledFuel \quad (92)$$

System Cost Elements

For Primary Products (boles & WT residues), $/CCF of material treated by the activity

Fell&Bunch: trees <=80 cf	12.70
Manual Fell, Limb, Buck: all trees	
Manual Fell, Limb, Buck: all log trees	
Manual Fell, Limb, Buck: trees >80cf	12.78
Manual Fell: trees <=80 cf	
Manual Fell: chip trees	
Harvest: trees <=80 cf	
Skid Bunched: all trees	35.42
Skid Unbunched: all trees	
Forward: trees <=80 cf	
Yard Unbunched: all trees	
Yard CTL: trees <=80 cf	
Process: log trees <=80 cf	8.18
Load: log trees	7.78
Load CTL: log trees <=80 cf	
Chip: chip whole trees	7.76
Chip: chip tree boles	
Chip CTL: chip tree boles	
Primary Product Move-In Costs, $/CCI	79.06

For Optional Residues, $/GT of additional residue recovered

$$Chip\ Loose\ Residues: from\ \log trees \leq 80\ cf = CostChipLooseRes \times CollectionOption \times InLimits1 \quad (93)$$

$$Residue\ MoveIn\ Costs, \frac{\$}{GT} = 0 \times CalcMoveIn \times CalcResidues \times InLimits1 \quad (94)$$

For All Products, $/ac

$$ChipLooseResiduesFromLogTreesLess80cf = CostChipLooseRes \times CalcResidues \times ResidueRecoveredOptional \times InLimits1 \quad (95)$$

$$FellAndBunchTreesLess80cf = \frac{CostFellBunch \times VolPerAcreST \times InLimits1}{100} \quad (96)$$

$$ManualFellLimbBuckTreesLarger80cf = CostManFLBLLT \times VolPerAcreLLT/100 \times InLimits1 \quad (97)$$

$$SkidBunchedAllTrees = CostSkidBun \times VolPerAcre/100 \times InLimits1 \quad (98)$$

$$ProcessLogTreesLess80cf = CostProcess \times VolPerAcreSLT/100 \times InLimits1 \quad (99)$$

$$LoadLogTrees = CostLoad \times VolPerAcreALT/100 \times InLimits1 \quad (100)$$

$$ChipWholeTrees = CostChipWT \times VolPerAcreCT/100 \times InLimits1 \quad (101)$$

$$Stump2TruckPrimaryProductWithoutMovein\ (Mech\ WT) = FellAndBunchTreesLess80cf + ManualFellLimbBuckTreesLarger80cf + SkidBunchedAllTrees + ProcessLogTreesLess80cf + LoadLogTrees + ChipWholeTrees \quad (102)$$

$$Movein4PrimaryProduct = MoveInCosts!\ G39 \times CalcMoveIn \times BoleVolCCF \times InLimits1 \quad (103)$$

$$OntoTruck4ResiduesWoMovein\ (Mech\ WT) = ChipLooseResiduesFromLogTreesLess80cf \quad (104)$$

$$Movein4Residues = 0 \times CalcMoveIn \times CalcResidues \times ResidueRecoveredOptional \times InLimits1 \quad (105)$$

System Cost Summaries

$$TotalPerAcre = Stump2Truck4PrimaryProductWithoutMovein + Movein4PrimaryProduct + OntoTruck4ResiduesWoMovein + Movein4Residues \quad (106)$$

$$TotalPerBoleCCF = \frac{TotalPerAcre}{BoleVolCCF} \quad (107)$$

$$TotalPerGT = \frac{TotalPerAcre}{TotalPrimaryProductsAndOptionalResidues} \quad (108)$$

Limits

$$MaximumLLTperAcre = none \quad (109)$$

$$MaxLLTasPercentALT = none \quad (110)$$

$$ExceededMaxLLT = 0 \quad (111)$$

$$AvgTreeSizeLimit4Chipping = 80 \quad (112)$$

$$AvgTreeSizeLimit4Processing = 80 \quad (113)$$

$$AvgTreeSizeLimit4ManualFellLimbBuck = 250 \quad (114)$$

$$AvgTreeSizeLimit4loading = 250 \quad (115)$$

$$AvgTreeSize4GrappleSkiddingOfBunchedTrees = 250 \quad (116)$$

$$\begin{aligned} ExceededMaxTreeVol = IF(OR(&TreeVolCT \\ &> AvgTreeSizeLimit4Chipping, TreeVolSLT \\ &> AvgTreeSizeLimit4Processing, TreeVolLLT \\ &> AvgTreeSizeLimit4ManualFellLimbBuck, TreeVolALT \\ &> AvgTreeSizeLimit4loading, TreeVol \\ &> AvgTreeSize4GrappleSkidding),1,0) \end{aligned} \quad (117)$$

$$SkiddingLimit(Slope, \%) = 40 \quad (118)$$

$$ExceededMaxSkidSlope = IF(Slope > SkiddingLimit, 1,0) \quad (119)$$

$$YardingDistLimit = 0 \quad (120)$$

$$ExceededMaxYardingDist = 0 \quad (121)$$

$$\begin{aligned} InLimits1 = IF(OR(&ExceededMaxLLT = 1, ExceededMaxTreeVol \\ &= 1, ExceededMaxSkidSlope = 1, ExceededMaxYardingDist \\ &= 1), NA(),1) \end{aligned} \quad (122)$$

Fell&Bunch

CostFellBunch

$$DistBetweenTrees = \sqrt{\frac{43560}{Max(Removals, 1)}} \quad (123)$$

I. Drive-To-Tree

A) Melroe Bobcat (Johnson, 79)

PMH – Per Productive Machine hour

$$\begin{aligned} &TimePerTreeIA \\ &= 0.204 + 0.00822 \times DistBetweenTrees + 0.02002 \times DBHST \\ &+ 0.00244 \times Slope \end{aligned} \quad (124)$$

$$VolPerPMHIA = \frac{TreeVolST \times 60}{TimePerTreeIA} \quad (125)$$

$$CostPerPMHIA = PMH\_DriveToTree \tag{126}$$

$$CostPerCCFIA = \frac{100 \times CostPerPMHIA}{VolPerPMHIA} \tag{127}$$

$$RelevanceIA = IF(DBHST < 10{,}1, IF(DBHST < 15{,}3 - DBHST/5{,}0)) \times IF(Slope < 10{,}1, IF(Slope < 20{,}2 - Slope/10{,}0)) \tag{128}$$

B) Chainsaw Heads (Greene&McNeel, 91)

$$CutsIB = 1.1 \tag{129}$$

$$TimePerTreeIB = (-0.0368 + 0.02914 \times DBHST + 0.00289 \times DistBetweenTrees + 0.2134 \times CutsIB) \times (1 + CSlopeFB_{Harv}) \tag{130}$$

$$VolPerPMHIB = \frac{TreeVolST \times 60}{TimePerTreeIB} \tag{131}$$

$$CostPerPMHIB = PMH\_DriveToTree \tag{132}$$

$$CostPerCCFIB = \frac{100 \times CostPerPMHIB}{VolPerPMHIB} \tag{133}$$

$$RelevanceIB = IF(DBHST < 15{,}1, IF(DBHST < 20{,}4 - DBHST/5{,}0)) * IF(Slope < 10{,}1, IF(Slope < 20{,}2 - Slope/10{,}0)) \tag{134}$$

C) Intermittent Circular Sawheads (Greene&McNeel, 91)

$$CutsIC = 1.01 \tag{135}$$

$$TimePerTreeIC = (-0.4197 + 0.01345 \times DBHST + 0.001245 \times DistBetweenTrees + 0.7271 \times CutsIC) \times (1 + CSlopeFB_{Harv}) \tag{136}$$

$$VolPerPMHIC = \frac{TreeVolST \times 60}{TimePerTreeIC} \tag{137}$$

$$CostPerPMHIC = = PMH\_DriveToTree \tag{138}$$

$$CostPerCCFIC = \frac{100 \times CostPerPMHIC}{VolPerPMHIC} \tag{139}$$

$$RelevanceIC = IF(DBHST < 15{,}1, IF(DBHST < 20{,}4 - DBHST/5{,}0)) \times IF(Slope < 10{,}1, IF(Slope < 20{,}2 - Slope/10{,}0)) \tag{140}$$

D) Hydro-Ax 211 (Hartsough, 01)

$$TreesPerAccumID = MAX(1{,}14.2 - 2.18 \times DBHST + 0.0799 \times DBHST^2) \tag{141}$$

$$TimePerAccumID = 0.114 + 0.266 + 0.073 \times TreesPerAccumID + 0.00999 \times TreesPerAccumID \times DBHST \tag{142}$$

$$TreesPerPMHID = \frac{60 \times TreesPerAccumID}{TimePerAccumID} \quad (143)$$

$$VolPerPMHID = TreeVolST \times TreesPerPMHID \quad (144)$$

$$CostPerPMHID = PMH\_DriveToTree \quad (145)$$

$$CostPerCCFID = \frac{100 \times CostPerPMHID}{VolPerPMHID} \quad (146)$$

$$RelevanceID = IF(DBHST < 10,1,IF(DBHST < 15,3 - DBHST/5,0)) \times IF(Slope < 10,1,IF(Slope < 20,2 - Slope/10,0)) \quad (147)$$

II. Swing Boom

A) Drott (Johnson, 79) not used at present

$$TimePerTreeIIA = 0.388 + 0.0137 \times DistBetweenTrees + 0.0398 \times Slope \quad (148)$$

$$VolPerPMHIIA = \frac{TreeVolST \times 60}{TimePerTreeIIA} \quad (149)$$

$$CostPerPMHIIA = PMH\_SwingBoom \quad (150)$$

$$CostPerCCFIIA = \frac{100 \times CostPerPMHIIA}{VolPerPMHIIA} \quad (151)$$

$$RelevanceIIA = 0 \quad (152)$$

$$(Former\ Relevance\ Weight = IF(DBHST < 12,1,IF(DBHST < 18,3 - DBHST/6,0)) * IF(Slope < 20,1,IF(Slope < 30,3 - Slope/10,0)) \quad (153)$$

B) Timbco 2520&Cat 227 (Johnson, 88)

$$BoomReachIIB = 24 \quad (154)$$

$$TreeInReachIIB = \frac{RemovalsST \times \pi \times BoomReachIIB^2}{43560} \quad (155)$$

$$TreesPerCycleIIB = MAX(1, TreeInReachIIB) \quad (156)$$

$$TimePerCycleIIB = (0.242 + 0.1295 \times TreesPerCycleIIB + 0.0295 \times DBHST \times TreesPerCycleIIB) \times (1 + CSlopeFB_{Harv}) \quad (157)$$

$$TimePerTreeIIB = \frac{TimePerCycleIIB}{TreesPerCycleIIB} \quad (158)$$

$$VolPerPMHIIB = \frac{TreeVolST \times 60}{TimePerTreeIIB} \quad (159)$$

$$CostPerPMHIIB = PMH\_SwingBoom \times NonSelfLevelCabDummy + PMH\_SelfLevel \times (1 - NonSelfLevelCabDummy) \quad (160)$$

$$CostPerCCFIIB = \frac{100 \times CostPerPMHIIB}{VolPerPMHIIB} \quad (161)$$

$$RelevanceIIB = IF(DBHST < 15{,}1, IF(DBHST < 20{,}4 - DBHST/5{,}0)) \times IF(Slope < 5{,}0, IF(Slope < 20, -1/3 + Slope/15{,}1)) \quad (162)$$

C) JD 693B&TJ Timbco 2518 (Gingras, 88)

$$UnmerchTreesPerHaIIC = 285 \quad (163)$$

$$UnmerchPerMerchIIC = MIN(1.5, \frac{285}{2.47 \times RemovalsST}) \quad (164)$$

$$BoomReachIIC = 24 \quad (165)$$

$$TreesInReachIIC = \frac{RemovalsST \times \pi \times BoomReachIIC^2}{43560} \quad (166)$$

$$ObsTreesPerCycleIIC = (4.36 + 9 - (0.12 + 0.34) \times DBHST + 0.00084 \times 2.47 \times RemovalsST)/2 \quad (167)$$

$$TreesPerCycleIIC = MAX(1, MIN(TreesInReachIIC, ObsTreesPerCycleIIC)) \quad (168)$$

$$TreesPerPMHIIC = (127.8 + 21.2 \times TreesPerCycleIIC - 63.1 \times UnmerchPerMerchIIC + 0.033 \times UnmerchTreesPerHaIIC)/(1 + CSlopeFB\_Harv) \quad (169)$$

$$VolPerPMHIIC = TreeVolST \times TreesPerPMHIIC \quad (170)$$

$$CostPerPMHIIC = PMH\_SwingBoom \times NonSelfLevelCabDummy + PMH\_SelfLevel \times (1 - NonSelfLevelCabDummy) \quad (171)$$

$$CostPerCCFIIC = 100 \times CostPerPMHIIC/VolPerPMHIIC \quad (172)$$

$$RelevanceIIC = IF(DBHST < 12{,}1, IF(DBHST < 18{,}3 - DBHST/6{,}0)) \times IF(Slope < 5{,}0, IF(Slope < 20, -1/3 + Slope/15{,}1)) \quad (173)$$

D) Timbco (Gonsier&Mandzak, 87)

$$TimePerTreeIID = (0.324 + 0.00138 \times DBHST^2) \times (1 + CSlopeFB\_Harv + CRemovalsFB\_Harv) \quad (174)$$

$$VolPerPMHIID = TreeVolST/(TimePerTreeIID/60) \quad (175)$$

$$CostPerPMHIID = PMH\_SelfLevel \quad (176)$$

$$CostPerCCFIID = 100 \times CostPerPMHIID/VolPerPMHIID \quad (177)$$

$$RelevanceIID = IF(DBHST < 15{,}1, IF(DBHST < 20{,}4 - DBHST/5{,}0)) \times IF(Slope < 15{,}0, IF(Slope < 35, -3/4 + Slope/20{,}1)) \quad (178)$$

E) FERIC Generic (Gingras, J.F., 96. The cost of product sorting during harvesting. FERIC Technical Note TN-245)

$$VolPerPMHIIE = (50.338/0.028317 \times (TreeVolST * 0.028317)^{0.3011})/(1 + CSlopeFB\_Harv + CRemovalsFB\_Harv) \quad (179)$$

$$CostPerPMHIIE = PMH\_SwingBoom \times NonSelfLevelCabDummy + PMH\_SelfLevel \times (1 - NonSelfLevelCabDummy) \quad (180)$$

$$CostPerCCFIIE = 100 \times CostPerPMHIIE/VolPerPMHIIE \quad (181)$$

$$RelevanceIIE = IF(Slope < 5{,}0, IF(Slope < 20, -1/3 + Slope/15{,}1)) \quad (182)$$

F) (Plamondon, J. 1998. Trials of mechanized tree-length harvesting in eastern Canada. FERIC Technical Note TN-273)

$$VolPerPMHIIF = (5/0.028317 + 57.7 \times TreeVolST)/(1 + CSlopeFB\_Harv + CRemovalsFB\_Harv) \quad (183)$$

$$CostPerPMHIIF = PMH\_SwingBoom \times NonSelfLevelCabDummy + PMH\_SelfLevel \times (1 - NonSelfLevelCabDummy) \quad (184)$$

$$CostPerCCFIIF = 100 \times CostPerPMHIIF/VolPerPMHIIF \quad (185)$$

$$RelevanceIIF = IF(TreeVolST < 20{,}1, IF(TreeVolST < 50{,}5/3 - TreeVolST/30{,}0)) \times IF(Slope < 5{,}0, IF(Slope < 20, -1/3 + Slope/15{,}1)) \quad (186)$$

G) Timbco 420 (Hartsough, B., E. Drews, J. McNeel, T. Durston and B. Stokes. 97. Comparison of mechanized systems for thinning ponderosa pine and mixed conifer stands. Forest Products Journal 47(11/12):59-68)

$$HybridIIG = 0 \quad (187)$$

$$DeadIIG = 0 \quad (188)$$

$$DelayFracIIG = 0.0963 \quad (189)$$

$$BoomReachIIG = 24 \quad (190)$$

$$TreesInReachIIG = RemovalsST \times \pi \times BoomReachIIG^2/43560 \quad (191)$$

$$TreesPerAccumIIG = MAX(1,1.81 - 0.0664 \times DBHST + 3.64/DBHST - 0.0058 \times 20 - 0.27 * 0 - 0.1 \times 0) \quad (192)$$

$$MoveFracIIG = 0.5/(TRUNC(TreesInReachIIG/TreesPerAccumIIG) + 1) \quad (193)$$

$$MoveIIG = 0.192 + 0.00779 \times (BoomReachIIG + DistBetweenTrees) + 0.35 \times HybridIIG \quad (194)$$

$$FellIIG = 0.285 + 0.126 \times TreesPerAccumIIG + 0.0176 \times DBHST \times TreesPerAccumIIG - 0.0394 \times DeadIIG \quad (195)$$

$$TimePerAccumIIG = MoveFracIIG \times MoveIIG + FellIIG \quad (196)$$

$$TimePerTreeIIG = (TimePerAccumIIG \times (1 + DelayFracIIG)/TreesPerAccumIIG) \times (1 + CSlopeFB\_Harv) \quad (197)$$

$$VolPerPMHIIG = TreeVolST/TimePerTreeIIG \times 60 \quad (198)$$

$$CostPerPMHIIG = PMH\_SwingBoom \times NonSelfLevelCabDummy + PMH\_SelfLevel \times (1 - NonSelfLevelCabDummy) \quad (199)$$

$$CostPerCCFIIG = 100 \times CostPerPMHIIG/VolPerPMHIIG \quad (200)$$

$$RelevanceIIG = IF(DBHST < 15,1,IF(DBHST < 20,4 - DBHST/5,0)) \times IF(Slope < 5,0,IF(Slope < 20,-1/3 + Slope/15,1)) \quad (201)$$

III. User-Defined

$$UserDefinedVolPerPMH = 0.001 \quad (202)$$

$$UserDefinedCostPerPMH = null \quad (203)$$

$$UserDefinedCostPerCCF = 100 \times UserDefinedCostPerPMH/UserDefinedVolPerPMH \quad (204)$$

$$UserDefinedRelevance = 0 \quad (205)$$

Felling&Bunching Summary

$$
\begin{aligned}
WeightedAverage\ = IF(&TreeVolST \\
&> 0, CHardwoodST \times 100 \times (CostPerPMHIA \times RelevanceIA \\
&+ CostPerPMHIB \times RelevanceIB + CostPerPMHIC \times RelevanceIC \\
&+ CostPerPMHID \times RelevanceID \\
&+ CostPerPMHIIA \times RelevanceIIA \\
&+ CostPerPMHIIB \times RelevanceIIB \\
&+ CostPerPMHIIC \times RelevanceIIC \\
&+ CostPerPMHIID \times RelevanceIID \\
&+ CostPerPMHIIE \times RelevanceIIE \\
&+ CostPerPMHIIF \times RelevanceIIF \\
&+ CostPerPMHIIG \times RelevanceIIG \\
&+ UserDefinedCostPerPMH \times UserDefinedRelevance) \\
&/(VolPerPMHIA \times RelevanceIA + VolPerPMHIB \times RelevanceIB \\
&+ VolPerPMHIC \times RelevanceIC + VolPerPMHID \times RelevanceID \\
&+ VolPerPMHIIA \times RelevanceIIA + VolPerPMHIIB \times RelevanceIIB \\
&+ VolPerPMHIIC \times RelevanceIIC + VolPerPMHIID \times RelevanceIID \\
&+ VolPerPMHIIE \times RelevanceIIE + VolPerPMHIIF \times RelevanceIIF \\
&+ VolPerPMHIIG \times RelevanceIIG \\
&+ UserDefinedVolPerPMH \times UserDefinedRelevance),0)
\end{aligned}
\tag{206}
$$

Felling (large log trees)

$$WalkDistLLT\ = \sqrt{43560/MAX(RemovalsLLT, 1)} \tag{207}$$

Part I: Felling Only

A (McNeel, 94)

$$
\begin{aligned}
&SelectionTimePerTreelltA \\
&= 0.568 + 0.0193 * 0.305 * WalkDistLLT + 0.0294 * 2.54 * DBHLLT
\end{aligned}
\tag{208}
$$

$$
\begin{aligned}
&ClearcutTimePerTreelltA \\
&= 0.163 + 0.0444 * 0.305 * WalkDistLLT + 0.0323 * 2.54 * DBHLLT
\end{aligned}
\tag{209}
$$

$$
\begin{aligned}
TimePerTreelltA = IF(&PartialCut = 1, SelectionTimePerTreelltA, \\
&MIN(SelectionTimePerTreelltA, ClearcutTimePerTreelltA))
\end{aligned}
\tag{210}
$$

$$VolPerPMHlltA = TreeVolLLT/(TimePerTreelltA/60) \tag{211}$$

$$PMH\_Chainsaw = 95.65 \tag{212}$$

$$CostPerCCFlltA = 100 * PMH\_Chainsaw/VolPerPMHlltA \tag{213}$$

$$RelevancelltA = 1 \quad (214)$$

B (Peterson, 87)

$$TimePerTreelltB = IF(DBHLLT < 10, 0.33 + 0.012 * DBHLLT, 0.1 + 0.0111 * DBHLLT\text{^}1.496) \quad (215)$$

$$VolPerPMHlltB = TreeVolLLT/(TimePerTreelltB/60) \quad (216)$$

$$CostPerCCFlltB = 100 * PMH\_Chainsaw/VolPerPMHlltB \quad (217)$$

$$RelevancelltB = 1 \quad (218)$$

C (Keatley, 2000)

$$TimePerTreelltC = SQRT(4.58 + 0.07 * WalkDistLLT + 0.16 * DBHLLT) \quad (219)$$

$$VolPerPMHlltC = TreeVolLLT/(TimePerTreelltC/60) \quad (220)$$

$$CostPerCCFlltC = 100 * PMH\_Chainsaw/VolPerPMHlltC \quad (221)$$

$$RelevancelltC = 1 \quad (222)$$

D (Andersson, B. and G. Young, 98. Harvesting coastal second growth forests: summary of harvesting system performance. FERIC Technical Report TR-120)

$$TimePerTreelltD = 1.082 + 0.01505 * TreeVolLLT - 0.634/TreeVolLLT \quad (223)$$

$$VolPerPMHlltD = TreeVolLLT/(TimePerTreelltD/60) \quad (224)$$

$$CostPerCCFlltD = 100 * PMH\_Chainsaw/VolPerPMHlltD \quad (225)$$

$$RelevancelltD = IF(TreeVolLLT < 5, 0, IF(TreeVolLLT < 15, -0.5 + TreeVolLLT/10, IF(TreeVolLLT < 90, 1, IF(TreeVolLLT < 180, 2 - TreeVolLLT/90, 0)))) \quad (226)$$

E User-Defined Felling Only

$$VolPerPMHlltE = 0.001 \quad (227)$$

$$CostPerCCFlltE = 100 * PMH\_Chainsaw/VolPerPMHlltE \quad (228)$$

$$RelevancelltE = 0 \quad (229)$$

Summary

$$CostManFellLLT == IF(TreeVolLLT > 0, CHardwoodLLT * 100 * (PMH\_Chainsaw * RelevancelltA + PMH\_Chainsaw * RelevancelltB + PMH\_Chainsaw * RelevancelltC + PMH\_Chainsaw * RelevancelltD + PMH\_Chainsaw * RelevancelltE)/(RelevancelltA * VolPerPMHlltA + RelevancelltB * VolPerPMHlltB + RelevancelltC * VolPerPMHlltC + RelevancelltD * VolPerPMHlltD + RelevancelltE * VolPerPMHlltE), 0) \quad (230)$$

Part II: Felling, Limbing & Bucking

A (Kellogg&Olsen, 86)

$$EastsideAdjustment = 1.2 \tag{231}$$

$$ClearcutAdjustment = 0.9 \tag{232}$$

$$\begin{aligned} TimePerTreelltIIA = EastsideAdjustment * IF(PartialCut = 1{,}1, IF(PartialCut \\ = 0, ClearcutAdjustment, \#N/A)) * (1.33 + 0.0187 * WalkDistLLT \\ + 0.0143 * Slope + 0.0987 * TreeVolLLT + 0.14) \end{aligned} \tag{233}$$

$$VolPerPMHlltIIA = TreeVolLLT/(TimePerTreelltIIA/60) \tag{234}$$

$$CostPerCCFlltIIA = 100 * PMH\_Chainsaw/VolPerPMHlltIIA \tag{235}$$

$$RelevancelltIIA = 1 \tag{236}$$

B (Kellogg, L., M. Miller and E. Olsen, 1999) Skyline thinning production and costs: experience from the Willamette Young Stand Project. Research Contribtion 21. Forest Research Laboratory, Oregon State University, Corvallis.

$$LimbslltIIB = 31.5 \tag{237}$$

$$LogslltIIB = LogsPerTreeLLT \tag{238}$$

$$WedgelltIIB = 0.02 \tag{239}$$

$$CorridorlltIIB = 0.21 \tag{240}$$

$$NotBetweenOpeningslltIIB = 1 \tag{241}$$

$$OpeningslltIIB = 0 \tag{242}$$

$$HeavyThinlltIIB = IF(PartialCut, 0{,}1) \tag{243}$$

$$DelayFraclltIIB = 0.25 \tag{244}$$

$$\begin{aligned} TimePerTreelltIIB \\ = (-0.465 + 0.102 * DBHLLT + 0.016 * LimbslltIIB + 0.562 \\ * LogslltIIB + 0.009 * Slope + 0.734 * WedgelltIIB + 0.137 \\ * CorridorlltIIB + 0.449 * NotBetweenOpeningslltIIB + 0.437 \\ * OpeningslltIIB + 0.426 * HeavyThinlltIIB) * (1 \\ + DelayFraclltIIB) \end{aligned} \tag{245}$$

$$VolPerPMHlltIIB=TreeVolLLT/(TimePerTreelltIIB/60) \tag{246}$$

$$CostPerCCFlltIIB = 100 * PMH\_Chainsaw/VolPerPMHlltIIB \tag{247}$$

$$RelevancelltIIB = 1 \tag{248}$$

C (Andersson, B. and G. Young, 98. Harvesting coastal second growth forests: summary of harvesting system performance. FERIC Technical Report TR-120)

$$DelayFraclltIIC = 0.197 \tag{249}$$

$$TimePerTreelltIIC = (1.772 + 0.02877 * TreeVolLLT - 2.6486/TreeVolLLT) * (1 + DelayFraclltIIC) \quad (250)$$

$$VolPerPMHlltIIC = TreeVolLLT/(TimePerTreelltIIC/60) \quad (251)$$

$$CostPerCCFlltIIC = 100 * PMH\_Chainsaw/VolPerPMHlltIIC \quad (252)$$

$$RelevancelltIIC = IF(TreeVolLLT < 5,0,IF(TreeVolLLT < 15,-0.5 + TreeVolLLT/10,1)) \quad (253)$$

D User-Defined Felling, Limbing & Bucking

$$VolPerPMHlltIID = 0.001 \quad (254)$$

$$CostPerCCFlltIID = 100 * PMH\_Chainsaw/VolPerPMHlltIID \quad (255)$$

$$RelevancelltIID = 0 \quad (256)$$

Summary

$$CostManFLBLLT = IF(TreeVolLLT > 0, CHardwoodLLT * 100 * (PMH\_Chainsaw * RelevancelltIIA + PMH\_Chainsaw * RelevancelltIIB + PMH\_Chainsaw * RelevancelltIIC + PMH\_Chainsaw * RelevancelltIID)/(RelevancelltIIA * VolPerPMHlltIIA + RelevancelltIIB * VolPerPMHlltIIB + RelevancelltIIC * VolPerPMHlltIIC + RelevancelltIID * VolPerPMHlltIID),0) \quad (257)$$

Skidding

Skidding Calculated Values

$$TurnVol = IF(PartialCut = 0,44.87,IF(PartialCut = 1,31.62,\#N/A)) * TreeVol\text{^}0.282 * CSlopeSkidForwLoadSize \quad (258)$$

$$LogsPerTurnS = TurnVol/LogVol \quad (259)$$

$$TreesPerTurnS = TurnVol/TreeVol \quad (260)$$

$$PMH\_SkidderB = 189.61 \quad (261)$$

$$PMH\_SkidderS = 133.92 \quad (262)$$

$$SkidderHourlyCost = PMH\_SkidderS * (1 - ManualMachineSize) + PMH\_SkidderB * ManualMachineSize \quad (263)$$

I Choker, Unbunched

$$MaxLogs = 10 \quad (264)$$

$$ChokerLogs = MIN(MaxLogs, LogsPerTurnS) \quad (265)$$

$$ChokerTurnVol = ChokerLogs * LogVol \quad (266)$$

IA CC (Johnson&Lee, 88)

$$WinchDistSkidIA = 25 \quad (267)$$

$$TurnTimeSkidIA = -15.58 + 0.345 * ChokerLogs + 0.037 * ChokerTurnVol + 4.05 * LN(YardDist + WinchDistSkidIA) \quad (268)$$

$$VolPerPMHskidIA = ChokerTurnVol/(TurnTimeSkidIA/60) \quad (269)$$

$$CostPerCCFSkidIA = 100 * SkidderHourlyCost/VolPerPMHskidIA \quad (270)$$

$$RelevanceSkidIA = IF(ChokerTurnVol < 90,1,IF(ChokerTurnVol < 180,2 - ChokerTurnVol/90,0)) \quad (271)$$

IB CC (Gibson&Egging, 73)

$$TurnTimeSkidIB = 2.74 + 0.726 * ChokerLogs + 0.00363 * ChokerTurnVol * BFperCF + 0.0002 * ChokerTurnVol * WoodDensity + 0.00777 * YardDist + 0.00313 * Slope\text{^}2 \quad (272)$$

$$VolPerPMHskidIB = ChokerTurnVol/(TurnTimeSkidIB/60) \quad (273)$$

$$CostPerCCFskidIB = 100 * SkidderHourlyCost/VolPerPMHskidIB \quad (274)$$

$$RelevanceSkidIB = 1 \quad (275)$$

IC CC (Schillings, 69) not used at present

$$TurnTimeSkidIC = 60 * ((0.122 + 0.089) + (0.000229 + 0.000704) * YardDist + (-0.00076 + 0.00127) * Slope + (0.0191 + 0.0118) * ChokerLogs)/2 \quad (276)$$

$$VolPerPMHskidIC = ChokerTurnVol/(TurnTimeSkidIC/60) \quad (277)$$

$$CostPerCCFskidIC = 100 * SkidderHourlyCost/VolPerPMHskidIC \quad (278)$$

$$RelevanceSkidIC = 0 \quad (279)$$

ID CC (Gardner, 79)

$$TurnTimeSkidID = 2.57 + 0.823 * ChokerLogs + 0.0054 * ChokerTurnVol * BFperCF + 0.0078 * 2 * YardDist \quad (280)$$

$$VolPerPMHskidID = ChokerTurnVol/(TurnTimeSkidID/60) \quad (281)$$

$$CostPerCCFskidID = 100 * SkidderHourlyCost/VolPerPMHskidID \quad (282)$$

$$RelevanceSkidID = 1 \quad (283)$$

IE Cat 518 or Cat D4H, cable (Andersson, B. and G. Young 1998. Harvesting coastal second growth forests: summary of harvesting system performance. FERIC Technical Report TR-120)

$$TurnTimeSkidIE = (7.36 + 0.0053 * YardDist) \quad (284)$$

$$VolPerPMHskidIE = ChokerTurnVol/(TurnTimeSkidIE/60) \quad (285)$$

$$CostPerCCFskidIE = 100 * SkidderHourlyCost/VolPerPMHskidIE \quad (286)$$

$$RelevanceSkidIE = IF(TreeVol < 5,0,IF(TreeVol < 15,-0.5 + TreeVol/10,IF(TreeVol < 75,1,IF(TreeVol < 150,2 - TreeVol/75,0)))) \quad (287)$$

II Grapple, Unbunched

$$IntMoveDistS = 17.0 \quad (288)$$

IIA Cat 518 (Johnson, 88)

$$TurnTimeSkidIIA = 0.518 + 0.0107 * YardDist + 0.0011 * Slope\text{^}3 + 1.62 * LN(LogsPerTurnS) \quad (289)$$

$$VolPerPMHskidIIA = TurnVol/(TurnTimeSkidIIA/60) \quad (290)$$

$$CostPerCCFskidIIA = 100 * SkidderHourlyCost/VolPerPMHskidIIA \quad (291)$$

$$RelevanceSkidIIA = IF(ButtDiam < 20,1,IF(ButtDiam < 25,5 - ButtDiam/5,0)) \quad (292)$$

IIB JD 648 (Gebhardt, 77)

$$GroundRatingSkidIIB = 1.1 \quad (293)$$

$$TypeOfCutSkidIIB = 1.5 * PartialCut \quad (294)$$

$$TurnTimeSkidIIB = 1.072 + 0.00314 * YardDist + 0.0192 * Slope + 0.315 * TypeOfCutSkidIIB + 0.489 * LogsPerTurnS - 0.819 * GroundRatingSkidIIB + 0.00469 * IntMoveDistS + 0.00139 * TurnVol * BFperCF \quad (295)$$

$$VolPerPMHskidIIB = TurnVol/(TurnTimeSkidIIB/60) \quad (296)$$

$$CostPerCCFskidIIB = 100 * SkidderHourlyCost/VolPerPMHskidIIB \quad (297)$$

$$RelecanceSkidIIB = 1 \quad (298)$$

III User-Defined Skidding Unbunched

$$VolPerPMHskidIII = 0.001 \quad (299)$$

$$CostPerCCFskidIII = 100 * SkidderHourlyCost/VolPerPMHskidIII \quad (300)$$

$$RelevanceSkidIII = 0 \quad (301)$$

IV Grapple, Bunched

IVA Grapple Skidders (Johnson, 88)

$$DeckHeightSkidIVA = 3 \tag{302}$$

$$TravEmptySkidIVA = -2.179 + 0.0362 * Slope + 0.711 * LN(YardDist) \tag{303}$$

$$LoadSkidIVA = MAX(0,0.882 + 0.0042 * Slope\text{^}2 - 0.000048 * (TreesPerTurnS)\text{^}3) \tag{304}$$

$$TravLoadedSkidIVA = -0.919 + 0.00081 * YardDist + 0.000062 * Slope\text{^}3 + 0.353 * LN(YardDist) \tag{305}$$

$$DeckSkidIVA = 0.063 + 0.55 * LN(DeckHeightSkidIVA) + 0.0076 * (DeckHeightSkidIVA) * (TreesPerTurnS) \tag{306}$$

$$TurnTImeSkidIVA = TravEmptySkidIVA + LoadSkidIVA + TravLoadedSkidIVA + DeckSkidIVA \tag{307}$$

$$VolPerPMHskidIVA = TurnVol/(TurnTImeSkidIVA/60) \tag{308}$$

$$CostPerCCFskidIVA = 100 * SkidderHourlyCost/VolPerPMHskidIVA \tag{309}$$

$$RelevanceSkidIVA = IF(ButtDiam < 15,1,IF(ButtDiam < 20,4 - ButtDiam/5,0)) \tag{310}$$

IVB Grapple Skidders (Tufts et al, 88)

$$EastsideAdjustmentSkidIVB = 1.3 \tag{311}$$

$$BunchSizeSkidIVB = TreesPerCycleIIB \tag{312}$$

$$BunchVolSkidIVB = TreeVol * BunchSizeSkidIVB \tag{313}$$

$$TurnWtSkidIVB = TurnVol * WoodDensity \tag{314}$$

$$BunchesPerTurnSkidIVB = MAX(1,TurnVol/BunchVolSkidIVB) \tag{315}$$

$$SkidderHpSkidIVB = 50.5 + 5.74 * SQRT(TreeVol) \tag{316}$$

$$TravEmptySkidIVB = (0.1905 * YardDist + 0.3557 * SkidderHpSkidIVB - 0.0003336 * YardDist * SkidderHpSkidIVB)/100 \tag{317}$$

$$GrappleSkidIVB = MIN(5,(-38.36 + 161.6 * BunchesPerTurnSkidIVB - 0.5599 * BunchesPerTurnSkidIVB * SkidderHpSkidIVB + 1.398 * BunchesPerTurnSkidIVB * BunchSizeSkidIVB)/100) \tag{318}$$

$$TravLoadedSkidIVB = (-34.52 + 0.2634 * YardDist + 0.7634 * SkidderHpSkidIVB - 0.00122 * YardDist * SkidderHpSkidIVB + 0.03782 * YardDist * BunchesPerTurnSkidIVB)/100 \quad (319)$$

$$UngrappleSkidIVB = MAX(0, (5.177 * BunchesPerTurnSkidIVB + 0.002508 * TurnWtSkidIVB - 0.00007944 * TurnWtSkidIVB * BunchesPerTurnSkidIVB * BunchSizeSkidIVB * BunchesPerTurnSkidIVB)/100) \quad (320)$$

$$CycletimeSkidIVB = EastsideAdjustmentSkidIVB * (TravEmptySkidIVB + GrappleSkidIVB + TravLoadedSkidIVB + UngrappleSkidIVB) \quad (321)$$

$$VolPerPMHskidIVB = TurnVol/(CycletimeSkidIVB/60) \quad (322)$$

$$CostPerCCFskidIVB = 100 * SkidderHourlyCost/VolPerPMHskidIVB \quad (323)$$

$$RelevanceSkidIVB = 0.50 \quad (324)$$

IVC John Deere 748E (Kosicki, K. 00. Productivities and costs of two harvesting trials in a western Alberta riparian zone. FERIC Advantage 1(19))

$$LoadingStopsSkidIVC = 2.1 \quad (325)$$

$$TurnTimeSkidIVC = 0.65 + 0.0054 * YardDist + 0.244 * LoadingStopsSkidIVC \quad (326)$$

$$VolPerPMHskidIVC = TurnVol/(TurnTimeSkidIVC/60) \quad (327)$$

$$CostPerCCFskidIVC = 100 * SkidderHourlyCost/VolPerPMHskidIVC \quad (328)$$

$$RelevanceSkidIVC = IF(TreeVol < 5,0, IF(TreeVol < 10, -1 + TreeVol/5, IF(TreeVol < 50,1, IF(TreeVol < 100,2 - TreeVol/50,0)))) \quad (329)$$

IVD Cat D5H TSK Custom Track (Henderson, B. 01. Roadside harvesting with low ground-presssure skidders in northwestern British Columbia. FERIC Advantage 2(54))

$$TurnTimeSkidIVD = 2.818 + 0.0109 * YardDist \quad (330)$$

$$VolPerPMHskidIVD = TurnVol/(TurnTimeSkidIVD/60) \quad (331)$$

$$CostPerCCFskidIVD = 100 * SkidderHourlyCost/VolPerPMHskidIVD \quad (332)$$

$$RelevanceSkidIVD = IF(TreeVol < 5,0, IF(TreeVol < 10, -1 + TreeVol/5, IF(TreeVol < 50,1, IF(TreeVol < 100,2 - TreeVol/50,0)))) \quad (333)$$

IVE JD 748_G-II & TJ 560 (Kosicki, K. 02. Productivity and cost of summer harvesting in a central Alberta mixedwood stand. FERIC Advantage 3(6))

$$BunchesPerTurnSkidIVE = BunchesPerTurnSkidIVB \quad (334)$$

$$TurnTimeSkidIVE = 0.649 + 0.0058 * YardDist + 0.581 * BunchesPerTurnSkidIVE \quad (335)$$

$$VolPerPMHskidIVE = TurnVol/(TurnTimeSkidIVE/60) \quad (336)$$

$$CostPerCCFskidIVE = 100 * SkidderHourlyCost/VolPerPMHskidIVE \quad (337)$$

$$RelevanceSkidIVE = IF(TreeVol < 30,1,IF(TreeVol < 60,2 - TreeVol/30,0)) \quad (338)$$

IVF Tigercat 635 (Boswell, B. 98. Vancouver Island mechanized thinning trials. FERIC Technical Note TN-271)

$$TurnTimeSkidIVF = 5.77 + 0.007 * YardDist \quad (339)$$

$$VolPerPMHskidIVF = TurnVol/(TurnTimeSkidIVF/60) \quad (340)$$

$$CostPerCCFskidIVF = 100 * SkidderHourlyCost/VolPerPMHskidIVF \quad (341)$$

$$RelevanceSkidIVF = IF(TreeVol < 5,0,IF(TreeVol < 10,-1 + TreeVol/5,IF(TreeVol < 100,1,IF(TreeVol < 150,3 - TreeVol/50,0)))) \quad (342)$$

IVG Tigercat 635 (Kosicki, K. 02. Evaluation of Trans-Gesco TG88C and Tigercat 635 grapple skidders working in central Alberta. FERIC Advantage 3(37))

$$TreesPerTurnSkidIVG = TreesPerTurnS \quad (343)$$

$$TurnTimeSkidIVG = 2.98 + 0.006 * YardDist + 0.27 * TreesPerTurnSkidIVG \quad (344)$$

$$VolPerPMHskidIVG = TurnVol/(TurnTimeSkidIVG/60) \quad (345)$$

$$CostPerCCFskidIVG = 100 * SkidderHourlyCost/VolPerPMHskidIVG \quad (346)$$

$$RelevanceSkidIVG = IF(TreeVol < 40,1,IF(TreeVol < 80,2 - TreeVol/40,0)) \quad (347)$$

IVH User-Defined Skidding Bunched

$$VolPerPMHskidIVH = 0.001 \quad (348)$$

$$CostPerCCFskidIVH = 100 * SkidderHourlyCost/VolPerPMHskidIVH \quad (349)$$

$$RelevanceSkidIVH = 0 \quad (350)$$

Skidding Summary

$$CostSkidUB = CHardwood * 100 * (SkidderHourlyCost * RelevanceSkidIA + SkidderHourlyCost * RelevanceSkidIB + SkidderHourlyCost * RelevanceSkidIC + SkidderHourlyCost * RelevanceSkidID + SkidderHourlyCost * RelevanceSkidIE + SkidderHourlyCost * RelevanceSkidIIA + SkidderHourlyCost * RelecanceSkidIIB + SkidderHourlyCost * RelevanceSkidIII)/(RelevanceSkidIA * VolPerPMHskidIA + RelevanceSkidIB * VolPerPMHskidIB + RelevanceSkidIC * VolPerPMHskidIC + RelevanceSkidID * VolPerPMHskidID + RelevanceSkidIE * VolPerPMHskidIE + RelevanceSkidIIA * VolPerPMHskidIIA + RelecanceSkidIIB * VolPerPMHskidIIB + RelevanceSkidIII * VolPerPMHskidIII) \quad (351)$$

$$CostSkidBun = CHardwood * 100 * (SkidderHourlyCost * RelevanceSkidIVA + SkidderHourlyCost * RelevanceSkidIVB + SkidderHourlyCost * RelevanceSkidIVC + SkidderHourlyCost * RelevanceSkidIVD + SkidderHourlyCost * RelevanceSkidIVE + SkidderHourlyCost * RelevanceSkidIVF + SkidderHourlyCost * RelevanceSkidIVG + SkidderHourlyCost * RelevanceSkidIVH)/(RelevanceSkidIVA * VolPerPMHskidIVA + RelevanceSkidIVB * VolPerPMHskidIVB + RelevanceSkidIVC * VolPerPMHskidIVC + RelevanceSkidIVD * VolPerPMHskidIVD + RelevanceSkidIVE * VolPerPMHskidIVE + RelevanceSkidIVF * VolPerPMHskidIVF + RelevanceSkidIVG * VolPerPMHskidIVG + RelevanceSkidIVH * VolPerPMHskidIVH) \quad (352)$$

Processing

$$PMH\_ProcessorS = 209.64 \text{ // hardcoded} \quad (353)$$

$$PMH\_ProcessorB = 265.46 \text{ // hardcoded} \quad (354)$$

Processing Calculated Values

$$ProcessorHourlyCost = PMH\_ProcessorS * (1 - MechMachineSize) + PMH\_ProcessorB * MechMachineSize \quad (355)$$

A) Hahn Stroke Processor (Gonsier&Mandzak, 87)

$$TimePerTreeProcessA = 1.26 * (0.232 + 0.0494 * DBHSLT) \quad (356)$$

$$VolPerPMHProcessA = TreeVolSLT/(TimePerTreeProcessA/60) \quad (357)$$

$$CostPerCCFprocessA = 100 * ProcessorHourlyCost/VolPerPMHProcessA \quad (358)$$

$$RelevanceProcessA = IF(DBHSLT < 15{,}1, IF(DBHSLT < 20{,}4 - DBHSLT/5{,}0)) \quad (359)$$

B) Stroke Processor (MacDonald, 90)

$$TimePerTreeProcessB = 0.153 + 0.0145 * ButtDiamSLT \quad (360)$$

$$VolPerPMHprocessB = TreeVolSLT/(TimePerTreeProcessB/60) \quad (361)$$

$$CostPerCCFprocessB = 100 * ProcessorHourlyCost/VolPerPMHprocessB \quad (362)$$

$$RelevanceProcessB = IF(ButtDiamSLT < 20{,}1, IF(ButtDiamSLT < 30{,}3 - ButtDiamSLT/10{,}0)) \quad (363)$$

C) Roger Stroke Processor (Johnson, 88)

$$TimePerTreeProcessC = -0.05 + 0.6844 * LogsPerTreeSLT + 5 * 10^{-8} * TreeVolSLT^2 \quad (364)$$

$$VolPerPMHprocessC = TreeVolSLT/(TimePerTreeProcessC/60) \quad (365)$$

$$CostPerCCFprocessC = 100 * ProcessorHourlyCost/VolPerPMHprocessC \quad (366)$$

$$RelevanceProcessC = 1 \quad (367)$$

D) Harricana Stroke Processor (Johnson, 88)

$$TimePerTreeProcessD = -0.13 + 0.001 * ButtDiamSLT^2 + 0.5942 * LogsPerTreeSLT \quad (368)$$

$$VolPerPMHprocessD = TreeVolSLT/(TimePerTreeProcessD/60) \quad (369)$$

$$CostPerCCFprocessD = 100 * ProcessorHourlyCost/VolPerPMHprocessD \quad (370)$$

$$RelevanceProcessD = 1 \quad (371)$$

E) Hitachi EX150/Keto 500 (Schroder&Johnson, 97)

$$TimePerTreeProcessE = (0.67 + 0.0116 * TreeVolSLT)^2 \quad (372)$$

$$VolPerPMHprocessE = TreeVolSLT/(TimePerTreeProcessE/60) \quad (373)$$

$$CostPerCCFprocessE = 100 * ProcessorHourlyCost/VolPerPMHprocessE \quad (374)$$

$$RelevanceProcessE = IF(TreeVolSLT < 50{,}1, IF(TreeVolSLT < 100{,}2 - TreeVolSLT/50{,}0)) \quad (375)$$

F) FERIC Generic (Gingras, J.F. 96. The cost of product sorting during harvesting. FERIC Technical Note TN-245)

$$VolPerPMHprocessF = (41.16/0.02832) * (TreeVolSLT/35.31)^{0.4902} \quad (376)$$

$$CostPerCCFprocessF = 100 * ProcessorHourlyCost/VolPerPMHprocessF \quad (377)$$

$$RelevanceProcessF = 1 \quad (378)$$

G) Valmet 546 Woodstar Processor (Holtzscher, M. and B. Lanford 1997 Tree diameter effects on costs and productivity of cut-to-length systems. For. Prod. J. 47(3):25-30)

$$TimePerTreeProcessG = -0.341 + 0.1243 * DBHSLT \quad (379)$$

$$VolPerPMHprocessG = TreeVolSLT/(TimePerTreeProcessG/60) \quad (380)$$

$$CostPerCCFprocessG = 100 * ProcessorHourlyCost/VolPerPMHprocessG \quad (381)$$

$$RelevanceProcessG = IF(TreeVolSLT < 20,1,IF(TreeVolSLT < 40,2 - TreeVolSLT/20,0)) \quad (382)$$

H) User-Defined

$$VolPerPMHprocessH = 0.001 \quad (383)$$

$$CostPerCCFprocessH = 100 * ProcessorHourlyCost/VolPerPMHprocessH \quad (384)$$

$$RelevanceProcessH = 0 \quad (385)$$

Processing Summary

$$\begin{aligned} CostProcess = IF(&TreeVolSLT \\ &> 0, CHardwoodSLT * 100 * (ProcessorHourlyCost \\ &* RelevanceProcessA + ProcessorHourlyCost * RelevanceProcessB \\ &+ ProcessorHourlyCost * RelevanceProcessC \\ &+ ProcessorHourlyCost * RelevanceProcessD \\ &+ ProcessorHourlyCost * RelevanceProcessE \\ &+ ProcessorHourlyCost * RelevanceProcessF \\ &+ ProcessorHourlyCost * RelevanceProcessG \\ &+ ProcessorHourlyCost \\ &* RelevanceProcessH)/(RelevanceProcessA * VolPerPMHProcessA \\ &+ RelevanceProcessB * VolPerPMHprocessB + RelevanceProcessC \\ &* VolPerPMHprocessC + RelevanceProcessD \\ &* VolPerPMHprocessD + RelevanceProcessE \\ &* VolPerPMHprocessE + RelevanceProcessF \\ &* VolPerPMHprocessF + RelevanceProcessG \\ &* VolPerPMHprocessG + RelevanceProcessH \\ &* VolPerPMHprocessH),0) \end{aligned} \quad (386)$$

Loading

$$ExchangeTrucks = 5 \quad (387)$$

$$PMH\_LoaderS = 146.74 \; // \; hardcoded \quad (388)$$

$$PMH\_LoaderB = 180.18 \; // \; hardcoded \quad (389)$$

Loading Calculated Values

$$LoadVolALT = LoadWeightLog * 2000/(WoodDensityALT * 100) \quad (390)$$

$$LoadVolSLT = LoadWeightLog * 2000/(WoodDensitySLT * 100) \quad (391)$$

$$LoaderHourlyCost = PMH\_LoaderS * (1 - ManualMachineSizeALT) + PMH\_LoaderB * ManualMachineSizeALT \quad (392)$$

I. Loading Full-Length Logs

A) Front-End Loader (Vaughan, 89)

$$TimePerLoadIA = 22 - 0.129 * LogVolALT + ExchangeTrucks \quad (393)$$

$$VolPerPMHloadingIA = 100 * LoadVolALT/(TimePerLoadIA/60) \quad (394)$$

$$CostPerCCFloadingIA = 100 * LoaderHourlyCost/VolPerPMHloadingIA \quad (395)$$

$$RelevanceLoadingIA = IF(LogVolALT < 10,0,IF(LogVolALT < 40,-1/3 + LogVolALT/30,1)) \quad (396)$$

B) Knuckleboom Loader, Small Logs (Brown&Kellogg, 96)

$$CCFperPmin = 0.1 + 0.019 * LogVolALT \quad (397)$$

$$TimePerLoadIB = LoadVolALT/CCFperPmin + ExchangeTrucks \quad (398)$$

$$VolPerPMHloadingIB = 100 * LoadVolALT/(TimePerLoadIB/60) \quad (399)$$

$$CostPerCCFloadingIB = 100 * LoaderHourlyCost/VolPerPMHloadingIB \quad (400)$$

$$RelevanceLoadingIB = IF(LogVolALT < 10,1,IF(LogVolALT < 20,2 - LogVolALT/10,0)) \quad (401)$$

C) Loaders (Hartsough et al, 98)

$$TimePerCCFloadingIC = 0.66 + 46.2/DBHALT \quad (402)$$

$$TimePerLoadIC = TimePerCCFloadingIC * LoadVolALT \quad (403)$$

$$VolPerPMHloadingIC = 6000/TimePerCCFloadingIC \quad (404)$$

$$CostPerCCFloadingIC = 100 * LoaderHourlyCost/VolPerPMHloadingIC \quad (405)$$

$$RelevanceLoadingIC = 0.8 \;//\; hardcoded \quad (406)$$

D) Loaders (Jackson et al, 84)

$$VolPerPMHloadingID = 100 * (11.04 + 0.522 * LogVolALT - 0.00173 * LogVolALT^2) \quad (407)$$

$$CostPerCCFloadingID = 100 * LoaderHourlyCost/VolPerPMHloadingID \quad (408)$$

$$RelevanceLoadingID = IF(LogVolALT < 75,1,IF(LogVolALT < 100,4 - LogVolALT/25,0)) \quad (409)$$

E) User-Defined Load Full-Length Logs

$$VolPerPMHloadingIE = 0.001 \quad (410)$$

$$CostPerCCFloadingIE = 100 * LoaderHourlyCost/VolPerPMHloadingIE \quad (411)$$

$$RelevanceLoadingIE = 0 \quad (412)$$

II. Loading CTL Logs

A) Knuckleboom Loader, CTL Logs (Brown&Kellogg, 96)

$$CCFperPminLoadingIIA = 0.1 + 0.019 * CTLLogVol \quad (413)$$

$$TimePerLoadIIA = LoadVolSLT/CCFperPminLoadingIIA + ExchangeTrucks \quad (414)$$

$$VolPerPMHloadingIIA = 100 * LoadVolSLT/(TimePerLoadIIA/60) \quad (415)$$

$$CostPerCCFloadingIIA = 100 * LoaderHourlyCost/VolPerPMHloadingIIA \quad (416)$$

$$RelevanceLoadingIIA = IF(CTLLogVol < 10,1,IF(CTLLogVol < 20,2 - CTLLogVol/10,0)) \quad (417)$$

B) Loaders (Jackson et al, 84)

$$VolPerPMHloadingIIB = 100 * (11.04 + 0.522 * CTLLogVol - 0.00173 * CTLLogVol^2) \quad (418)$$

$$CostPerCCFloadingIIB = 100 * LoaderHourlyCost/VolPerPMHloadingIIB \quad (419)$$

$$RelevanceLoadingIIB = 0.5 \quad (420)$$

C) User-Defined Load CTL Logs

$$VolPerPMHloadingIIC = 0.001 \quad (421)$$

$$CostPerCCFloadingIIC = 100 * LoaderHourlyCost/VolPerPMHloadingIIC \quad (422)$$

$$RelevanceLoadingIIC = 0 \quad (423)$$

Loading Summary

I. Loading Full-Length Logs

$$\begin{aligned} CostLoad = IF(&include\_loading\_costs = TRUE, IF(TreeVolALT \\ &> 0, CHardwoodALT * 100 * (LoaderHourlyCost \\ &* RelevanceLoadingIA + LoaderHourlyCost * RelevanceLoadingIB \\ &+ LoaderHourlyCost * RelevanceLoadingIC + LoaderHourlyCost \\ &* RelevanceLoadingID + LoaderHourlyCost \\ &* RelevanceLoadingIE)/(RelevanceLoadingIA \\ &* VolPerPMHloadingIA + RelevanceLoadingIB \\ &* VolPerPMHloadingIB + RelevanceLoadingIC \\ &* VolPerPMHloadingIC + RelevanceLoadingID \\ &* VolPerPMHloadingID + RelevanceLoadingIE \\ &* VolPerPMHloadingIE),0),0) \end{aligned} \quad (424)$$

II. Loading CTL Logs

$$CostLoadCTL = IF(include\_loading\_costs = TRUE, IF(TreeVolSLT > 0, CHardwoodSLT * 100 * (LoaderHourlyCost * RelevanceLoadingIIA + LoaderHourlyCost * RelevanceLoadingIIB + LoaderHourlyCost * RelevanceLoadingIIC)/(RelevanceLoadingIIA * VolPerPMHloadingIIA + RelevanceLoadingIIB * VolPerPMHloadingIIB + RelevanceLoadingIIC * VolPerPMHloadingIIC),0),0) \quad (425)$$

Chipping

$$ExchangeVans = 5.3 \quad (426)$$

Chipping Calculated Values

$$LoadWeightDry = LoadWeightChip * (1 - MoistureContent) \quad (427)$$

$$TreeWeightDry = TreeVolCT * WoodDensityCT * (1 - MoistureContent) \quad (428)$$

$$CTLLogWeight = CTLLogVolCT * WoodDensityCT \quad (429)$$

$$CTLLogWeightDry = CTLLogWeight * (1 - MoistureContent) \quad (430)$$

$$ChipperHourlyCost = PMH\_ChipperS * (1 - ChipperSize) + PMH\_ChipperB * ChipperSize \quad (431)$$

$$PMH\_LoaderS = 146.74 \; // \; hardcoded \quad (432)$$

$$PMH\_ChipperS = 166.53 \; // \; hardcoded \quad (433)$$

$$PMH\_ChipperB = 244.64 \; // \; hardcoded \quad (434)$$

I. Chip Whole Trees

A) (Johnson, 89)

$$ChipperHP1A = MIN(700, MAX(200, 100 + 100 * SQRT(TreeVolCT))) \quad (435)$$

$$GTperPMHchippingIA = -17 + ChipperHP1A/6 \quad (436)$$

$$VolPerPMHchippingIA = GTperPMHchippingIA * 2000/WoodDensityCT \quad (437)$$

$$CostPerCCFchippingIA = 100 * ChipperHourlyCost/VolPerPMHchippingIA \quad (438)$$

$$RelevanceChippingIA = 1 \quad (439)$$

B) Morbark 22 (Hartsough, unpublished)

$$VolPerPMHchippingIB = MIN(4000, 463 * TreeVolCT^{0.668}) \quad (440)$$

$$CostPerCCFchippingIB = 100 * ChipperHourlyCost/VolPerPMHchippingIB \quad (441)$$

$$RelevanceChippingIB = 1 \quad (442)$$

C) Morbark 60/36 (Hartsough et al, 97)

$$ProbDelayFractionIC = 0.038 \quad (443)$$

$$LogsPerSwingIC = 1.2 + 338/TreeWeightDry \quad (444)$$

$$ChipTimePerSwingIC = 0.25 + 0.0264 * LogsPerSwingIC + 0.000498 * TreeWeightDry \quad (445)$$

$$SlashIC = 0.93 \quad (446)$$

$$TimePerVanIC = ChipTimePerSwingIC * (1 + ProbDelayFractionIC)/(TreeWeightDry * LogsPerSwingIC) * 2000 * LoadWeightDry + (SlashIC + ExchangeVans) \quad (447)$$

Type equation here. (448)

$$VolPerPMHchippingIC = LoadWeightChip/(WoodDensityCT/2000)/(TimePerVanIC/60) \quad (449)$$

$$CostPerCCFchippingIC = 100 * ChipperHourlyCost/VolPerPMHchippingIC \quad (450)$$

$$RelevanceChippingIC = IF(TreeWeightDry < 400,1, IF(TreeWeightDry < 800,2 - TreeWeightDry/400,0)) \quad (451)$$

D) User-Defined Chip Whole Trees

$$VolPerPMHchippingID = 0.001 \quad (452)$$

$$CostPerCCFchippingID = 100 * ChipperHourlyCost/VolPerPMHchippingID \quad (453)$$

$$RelevanceChippingID = 0 \quad (454)$$

II. Chain Flail DDC Whole Trees

A) adjusted from Chip Whole Trees

B) $FlailProdAdjustmentIIA = 0.9$ (455)

$$FlailHrlyCostAdjustmentIIA = 1.1 \quad (456)$$

$$CostPerPMHchippingIIA = FlailHrlyCostAdjustmentIIA * ChipperHourlyCost \quad (457)$$

$$CostPerCCFchippingIIA = (FlailHrlyCostAdjustmentIIA/FlailProdAdjustmentIIA) * CostChipWT \quad (458)$$

$$VolPerPMHchippingIIA = 100 * CostPerPMHchippingIIA/CostPerCCFchippingIIA \quad (459)$$

$$RelevanceChippingIIA = MAX(RelevanceChippingIA, RelevanceChippingIB, RelevanceChippingIC) \quad (460)$$

B) User-Defined Chain Flail DDC WT

$$VolPerPMHchippingIIB = 0.001 \quad (461)$$

$$CostPerCCFchippingIIB = 100 * ChipperHourlyCost/VolPerPMHchippingIIB \quad (462)$$

$$RelevanceChippingIIB = 0 \quad (463)$$

III. Chip CTL Logs

A) Morbark 27 (Drews et al, 98)

$$ProbDelayFractionIIIA = 0.111 \quad (464)$$

$$TimePerGTchippingIIIA = MAX(0.8, (2.05 - 0.00541 * CTLLogWeight) * (1 + ProbDelayFractionIIIA)) \quad (465)$$

$$TimePerVanIIIA = TimePerGTchippingIIIA * LoadWeightChip + ExchangeVans \quad (466)$$

$$VolPerPMHchippingIIIA = LoadWeightChip/(WoodDensityCT/2000)/(TimePerVanIIIA/60) \quad (467)$$

$$CostPerCCFchippingIIIA = 100 * ChipperHourlyCost/VolPerPMHchippingIIIA \quad (468)$$

$$RelevanceChippingIIIA = MAX(0.1, IF(CTLLogWeight < 100, 1, IF(CTLLogWeight < 200, 2 - CTLLogWeight/100, 0))) \quad (469)$$

B) Morbark 60/36 (Hartsough et al, 97)

$$ProdDelayFractionIIIB = 0.038 \quad (470)$$

$$LogsPerSwingIIIB = 1.2 + 338/CTLLogWeightDry \quad (471)$$

$$ChipTimePerSwingIIIB = 0.25 + 0.0264 * LogsPerSwingIIIB + 0.000498 * CTLLogWeightDry \quad (472)$$

$$SlashIIIB = 0.93 \quad (473)$$

$$TimePerVanIIIB = ChipTimePerSwingIIIB * (1 + ProdDelayFractionIIIB)/(CTLLogWeightDry * LogsPerSwingIIIB) * 2000 * LoadWeightDry + (SlashIIIB + ExchangeVans) \quad (474)$$

$$VolPerPMHchippingIIIB = LoadWeightChip/(WoodDensityCT/2000)/(TimePerVanIIIB/60) \quad (475)$$

$$CostPerCCFchippingIIIB = 100 * ChipperHourlyCost/VolPerPMHchippingIIIB \quad (476)$$

$$RelevanceChippingIIIB = IF(CTLLogWeightDry < 400,1,IF(CTLLogWeightDry < 800,2 - CTLLogWeightDry/400,0)) \quad (477)$$

C) User-Defined Chip CTL Logs

$$VolPerPMHchippingIIIC = 0.001 \quad (478)$$

$$CostPerCCFchippingIIIC = 100 * ChipperHourlyCost/VolPerPMHchippingIIIC \quad (479)$$

$$RelevanceChippingIIIC = 0 \quad (480)$$

IV. Chip Piled Loose Residues at Landing

A) Drum chippers (Desrochers, L., D. Puttock and M. Ryans. 95. Recovery of roadside residues using drum chippers. FERIC Technical Report TR-111)

$$BDTperPMHchippingIVA = 13.5 \quad (481)$$

$$BDTperPMHchippingIVA2 = 31 \quad (482)$$

$$BDTperPMHchippingIVAavg = AVERAGE(BDTperPMHchippingIVA: BDTperPMHchippingIVA2) \quad (483)$$

$$GTperPMHchippingIVA = BDTperPMHchippingIVAavg/MoistureContent \quad (484)$$

$$CostPerPMHchippingIVA = ChipperHourlyCost + PMH\_LoaderS \quad (485)$$

$$CostPerGTchippingIVA = CostPerPMHchippingIVA/GTperPMHchippingIVA \quad (486)$$

$$RelevanceChippingIVA = 1 \quad (487)$$

B) User-Defined Chip Piled Loose Residues at Landing

$$GTperPMHchippingIVB = 0.001 \quad (488)$$

$$CostPerGTchippingIVB = CostPerPMHchippingIVA/GTperPMHchippingIVB \quad (489)$$

$$RelevanceChippingIVB = 0 \quad (490)$$

V. Chip Bundles of Residue at Landing

A) Assume 50% faster than chipping loose residues

$$GTperPMHchippingVA = 1.5 * GTperPMHchippingIVA \quad (491)$$

$$CostPerGTchippingVA = CostPerPMHchippingIVA/GTperPMHchippingVA \quad (492)$$

$$RelevanceChippingVA = 1 \quad (493)$$

B) User-Defined Chip Bundles of Residue at Landing

$$GTperPMHchippingVB = 0.0001 \quad (494)$$

$$CostPerGTchippingVB = CostPerPMHchippingIVA/GTperPMHchippingVB \quad (495)$$

$$RelevanceChippingVB = 0 \quad (496)$$

Chipping Summary

I. Chip Whole Trees

$$CostChipWT = IF(TreeVolCT > 0, CHardwoodCT * 100 * (ChipperHourlyCost * RelevanceChippingIA + ChipperHourlyCost * RelevanceChippingIB + ChipperHourlyCost * RelevanceChippingIC + ChipperHourlyCost * RelevanceChippingID)/(RelevanceChippingIA * VolPerPMHchippingIA + RelevanceChippingIB * VolPerPMHchippingIB + RelevanceChippingIC * VolPerPMHchippingIC + RelevanceChippingID * VolPerPMHchippingID),0) \quad (497)$$

II. Chain Flail DDC WT

$$CostDDChipWT = IF(TreeVolCT > 0, CHardwoodCT * 100 * (CostPerPMHchippingIIA * RelevanceChippingIIA + ChipperHourlyCost * RelevanceChippingIIB)/(RelevanceChippingIIA * VolPerPMHchippingIIA + RelevanceChippingIIB * VolPerPMHchippingIIB),0) \quad (498)$$

III. Chip CTL Logs

$$CostChipCTL = IF(TreeVolCT > 0, CHardwoodCT * 100 * (ChipperHourlyCost * RelevanceChippingIIIA + ChipperHourlyCost * RelevanceChippingIIIB + ChipperHourlyCost * RelevanceChippingIIIC)/(RelevanceChippingIIIA * VolPerPMHchippingIIIA + RelevanceChippingIIIB * VolPerPMHchippingIIIB + RelevanceChippingIIIC * VolPerPMHchippingIIIC),0) \quad (499)$$

IV. Chip Piled Loose Residues at Landing

$$CostChipLooseRes = (CostPerPMHchippingIVA * RelevanceChippingIVA + CostPerPMHchippingIVA * RelevanceChippingIVB)/(RelevanceChippingIVA * GTperPMHchippingIVA + RelevanceChippingIVB * GTperPMHchippingIVB) \quad (500)$$

V. Chip Bundles of Residue at Landing

$$CostChipBundledRes = (CostPerPMHchippingIVA * RelevanceChippingVA + CostPerPMHchippingIVA * RelevanceChippingVB)/(RelevanceChippingVA * GTperPMHchippingVA + RelevanceChippingVB * GTperPMHchippingVB) \quad (501)$$