Carbon credits, working forests, and growth model predictions

Matthew Pelkki
George H. Clippert Endowed Chair
University of Arkansas-Monticello
School of Forest Resources
Arkansas Forest Resources Center

UofA UNIVERSITY OF ARKANSAS DIVISION OF AGRICULTURE

UAM THE UNIVERSITY OF ARKANSAS AT MONTICELLO

Estimating carbon for a "working" forest

- Inventory of current vegetation
- Application of yield equations to project biomass
- Estimate carbon dioxide from biomass
- Projections of carbon in future

Forest inventory

- Need to measure overstory and understory – all woody vegetation
- Decide what level of precision around biomass/carbon estimate is acceptable to the buyer (CCX)
- Conduct preliminary cruise to estimate variance
- Conduct final cruise to meet desired precision standards

An spreadsheet for determining necessary sample size

- Assumes “nested” overstory/understory plot structure
- Versions for variable- and fixed-radius plots
- Data from spreadsheet can be transformed into input file for growth model

Example preliminary cruise data

- Overstory plots – 1/10 acre fixed radius
- Understory plots – 1/100 acre fixed radius
- Breakpoint of 4.6” dbh
- Stand type – Oak-Gum-Cottonwood
- Site Index = 90 ft at 50 years for cottonwood
- 20 initial plots established
- Assume you want to know biomass/carbon to a precision of $\pm$ 10% of the mean to a 90% degree of confidence.

Example of 3 plots of data…

- Minimum necessary data
- Species codes match growth model
- Each tree's biomass determined using national biomass equations

PLOT NUM	TREE NUM	SPECIES	DBH
1	1	cw	12.0
1	2	cw	12.0
1	3	rl	9.0
1	4	cw	6.0
1	5	cw	7.0
1	6	cw	5.0
1	7	cw	9.0
1	8	cw	12.0
1	9	wk	7.0
1	10	rl	1.0
1	11	cw	3.0
2	1	pe	6.0
2	2	pe	14.0
2	3	pe	14.0
2	4	rl	5.0
2	5	pe	4.0
3	1	pe	8.0
3	2	pe	8.0
3	3	sy	7.0
3	4	wk	13.0
3	5	rl	6.0
3	6	rl	5.0
3	7	pe	8.0
3	8	pe	7.0
3	9	pe	8.0
3	10	sy	8.0
3	11	pe	8.0
3	12	pe	11.0
3	13	hb	1.0
3	14	pe	8.0

Results and interpretation

Sample Results

Enter your desired width of your confidence interval and the statistical strength from 1 (weak) to 6(exceptionally strong) for your mean estimate of biomass

Enter only data in green fields. All fields in yellow are automatically calculated! Remember, to refresh all calculations, press CNTRL+ALT+F9 keys.

Desired Confidence Interval HALF Width ±	10%	ALPHA =	0.1	**You will be**	**90.0%** **confident about this interval width**
Statistical "strength" (Enter 1 - 6)	2				

Number of Sample Plots Found in PlotData Sheet:	20	T-value	1.729
Required Number of Sample Plots to meet desired precision	65	**This is the total number of plots you need in your sample to reach desired precision!**	

You need 45 more plots to reach your desired precision.

Cruise Results

Mean Biomass (dry kg/ac)	**Mean Biomass (dry tons/acre)**	**Confidence Interval Lower Bound**	**Confidence Interval Upper Bound**
36,318.50	**40.0**	**32.77**	**47.13**

Currently your confidence interval half width is

± 18%

So, what if you could accept a confidence interval width of +15%?

Results and interpretation

Sample Results

Enter your desired width of your confidence interval and the statistical strength from 1 (weak) to 6(exceptionally strong) for your mean estimate of biomass

Enter only data in green fields. All fields in yellow are automatically calculated! Remember, to refresh all calculations, press CNTRL+ALT+F9 keys.

Desired Confidence Interval HALF Width ± 15%
Statistical "strength" (Enter 1 - 6) 2

ALPHA = 0.1 **You will be 90.0% confident about this interval width**

Number of Sample Plots Found in PlotData Sheet: 20

T-value 1.729

Required Number of Sample Plots to meet desired precision 29

This is the total number of plots you need in your sample to reach desired precision!

You need 9 more plots to reach your desired precision.

Cruise Results

Mean Biomass (dry kg/ac)	**Mean Biomass (dry tons/acre)**	**Confidence Interval Lower Bound**	**Confidence Interval Upper Bound**
36,318.50	**40.0**	**32.77**	**47.13**

Currently your confidence interval half width is ± 18%

Growth and Yield Model: FVS

- Forest Vegetation Simulator (FVS)
- USDA Forest Service developed – public domain software!
- Model Variants for entire United States
- Ability to input fixed or variable radius inventory data
- Harvest simulations can be programmed into system
- Ability to “self calibrate” to observed diameter and height growth data
- Carbon model extension available

FVS projections for a working forest

- 20-year old pine plantation, 27 acres
- Current conditions
  - 245 trees per acre
  - Basal area of 115 sq. ft. acre
  - 81 tons of merchantable volume
    - 13 tons chip-n-saw
    - 68 tons pulpwood
    - Current market value of $940 per acre
  - FVS projects 29 tons of CO_2 sequestered per acre at age 20
- Bare land value of $1400 per acre today, value of $1400 per acre in 20 years
- Will investigate management to a final harvest at age 35 years (15 years from now)
- Will assume regeneration scheme:
  - Site preparation and planting in year following harvest

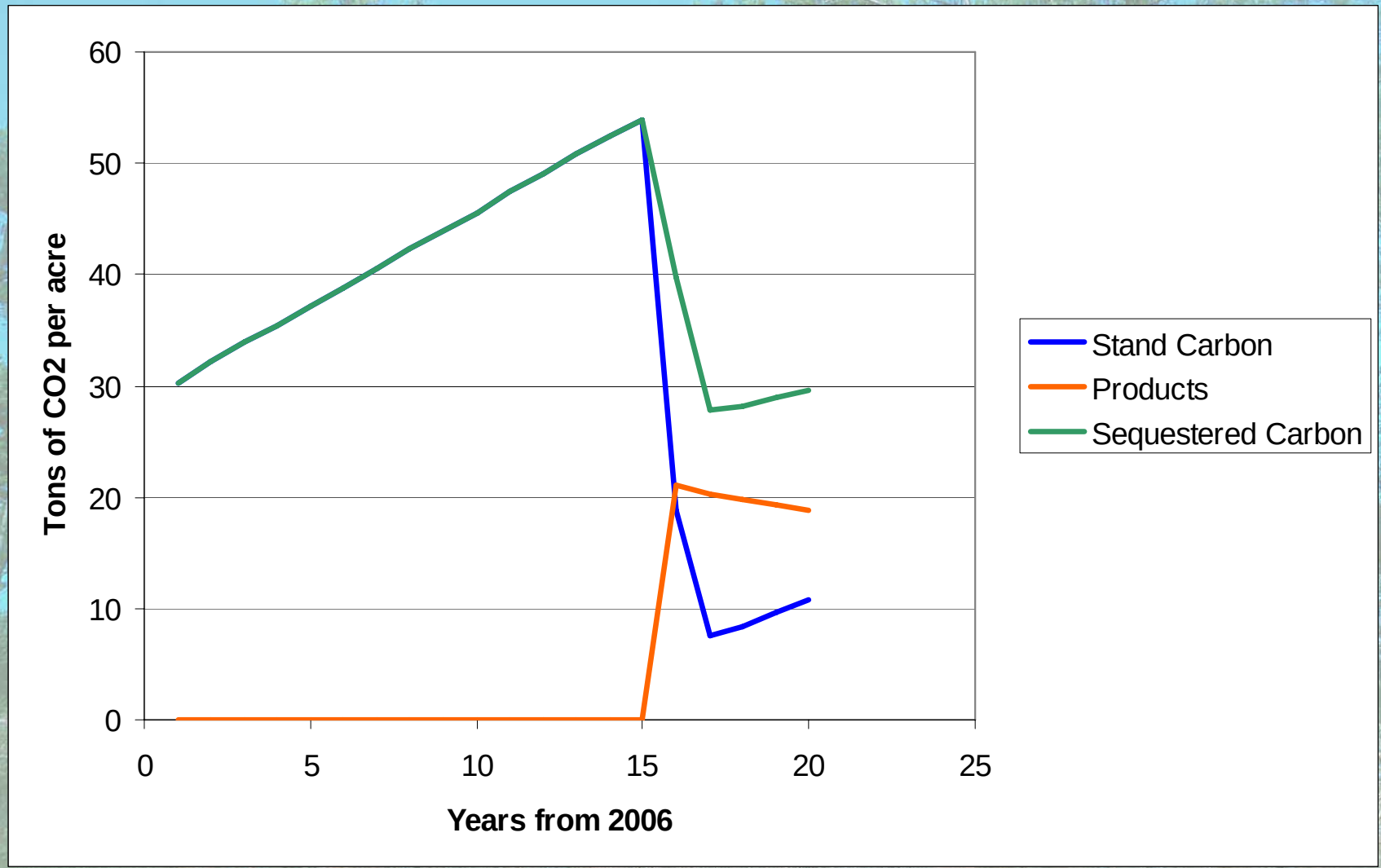
Some assumptions…

- Carbon prices are $3.00 per metric ton of CO_2
  - (Reduced price compensates for CCX assumption of 80% of carbon from models)
- Timber prices
  - $10 / ton for pulpwood
  - $20 / ton for CNS
  - $40 / ton for sawtimber
- Carbon prices increase at rate of 10% / year
- Timber prices increase at rate of 5% / year
- Landowner has **20-year** contract with carbon aggregator
- Will use all sequestered carbon in FVS (include dead wood, shrub layer, and wood in landfills)

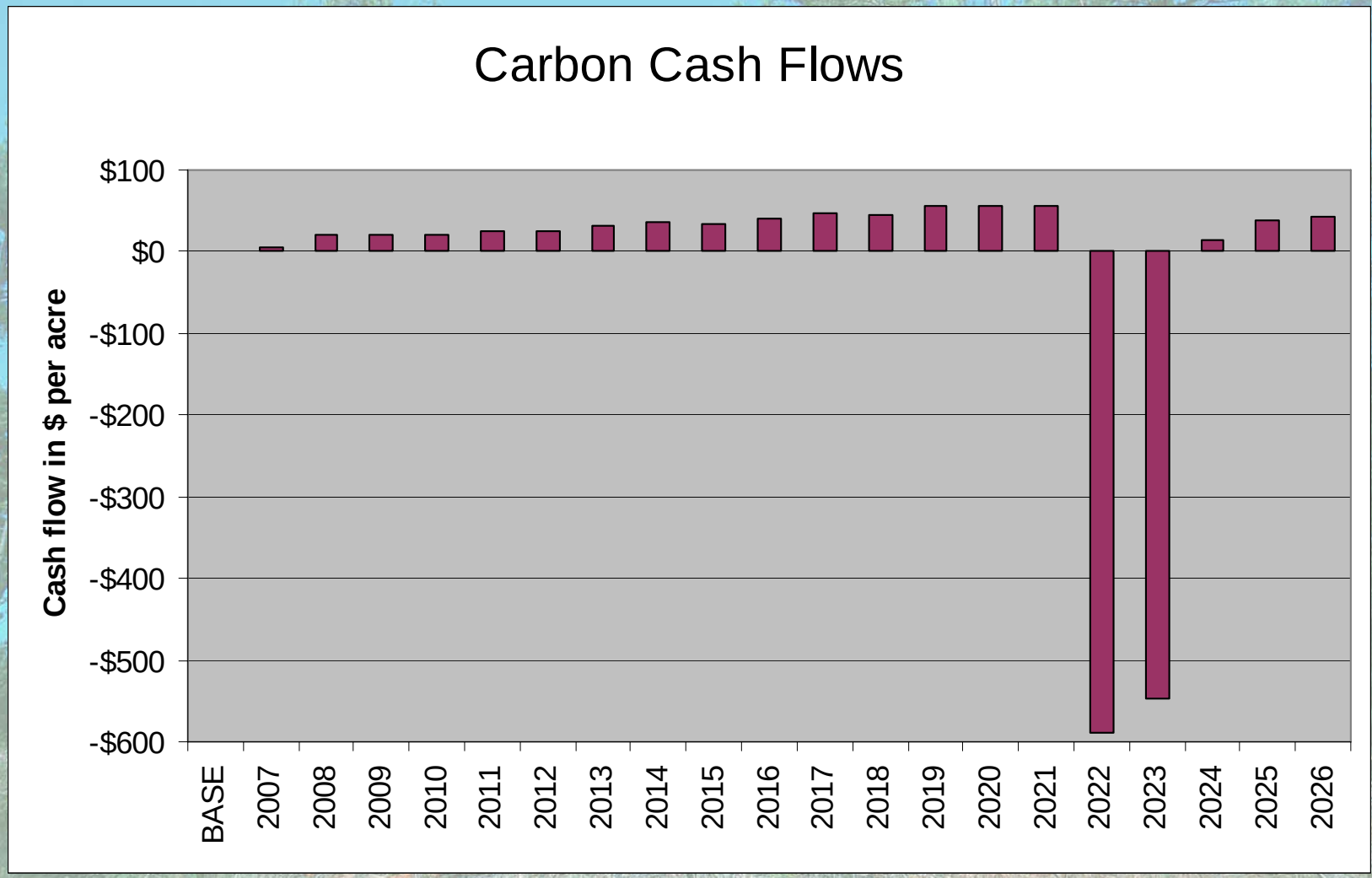
No management regime

- Allow stand to grow 15 years
- Final harvest of:
  - 4 tons pulp,
  - 82 tons chip-n-saw, and
  - 78 tons sawtimber
  - Revenue of $9952 per acre
- Site prep and regeneration in year immediately following final harvest

Carbon sequestered



Carbon cash flows



Comparison of separate components – timber and carbon credits

Year	Net Revenue of land and timber	10.10%	Net Revenue of carbon only	10.10%
BASE	($2,340)	($2,340)	$0	$0
2007	$0	$0	$6	$5
2008	$0	$0	$21	$17
2009	$0	$0	$22	$16
2010	$0	$0	$20	$14
2011	$0	$0	$25	$15
2012	$0	$0	$26	$14
2013	$0	$0	$32	$16
2014	$0	$0	$35	$16
2015	$0	$0	$34	$14
2016	$0	$0	$40	$15
2017	$0	$0	$47	$16
2018	$0	$0	$46	$14
2019	$0	$0	$56	$16
2020	$0	$0	$55	$14
2021	$0	$0	$57	$13
2022	$9,952	$2,136	($589)	($126)
2023	($250)	($49)	($547)	($107)
2024	$0	$0	$15	$3
2025	$0	$0	$39	$6
2026	$1,733	$253	$43	$6
		$0		$2

Land and timber rate of return over 20 years is 10.1%

At 10.1% cost of capital, present value of carbon credits is positive but only $2/acre!

15-year carbon contract

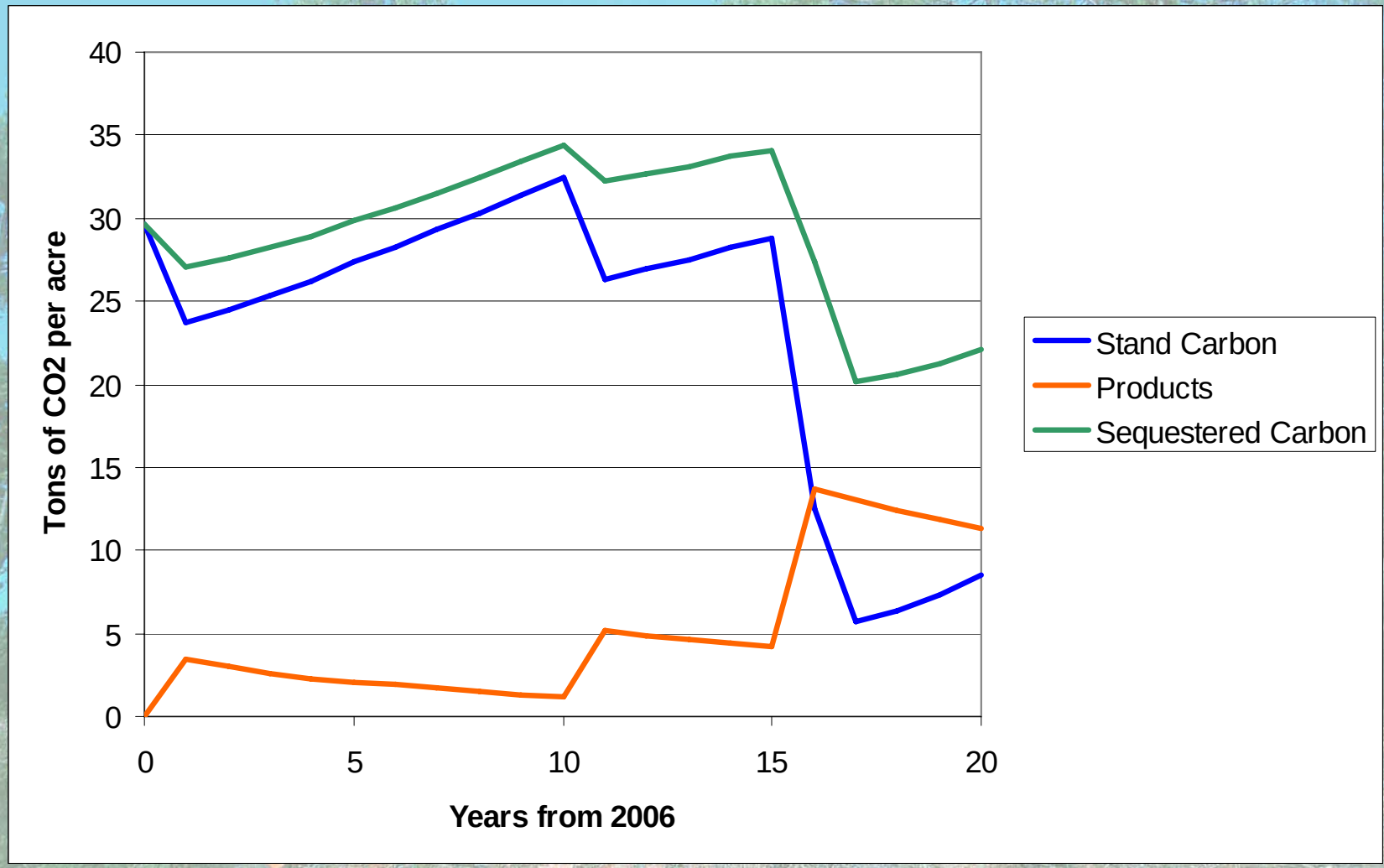
Year	Land Value	Carbon Trading Reciepts	Timber Cash Flows	Net Revenue Timber + Carbon	10.73%	10.10%
BASE	($1,400)		($940)	($2,340)	($2,340)	
2007		$6.00		$6	$5	$5
2008		$20.90		$21	$17	$17
2009		$21.78		$22	$16	$16
2010		$19.97		$20	$13	$14
2011		$24.89		$25	$15	$15
2012		$25.77		$26	$14	$14
2013		$31.89		$32	$16	$16
2014		$35.08		$35	$16	$16
2015		$34.30		$34	$14	$14
2016		$40.09		$40	$14	$15
2017		$46.69		$47	$15	$16
2018		$45.65		$46	$13	$14
2019		$56.49		$56	$15	$16
2020		$55.24		$55	$13	$14
2021		$56.96		$57	$12	$13
2022			$9,952	$9,952	$1,949	
2023			-$250	($250)	($44)	
2024					$0	
2025					$0	
2026	$1,400		$333	$1,733	$226	
					$0	$219

- Assume carbon contract for 2007-2021
- Overall rate of return increases to 10.7%
- Value of carbon contract at 10.1% cost of capital is $219 per acre in today's terms

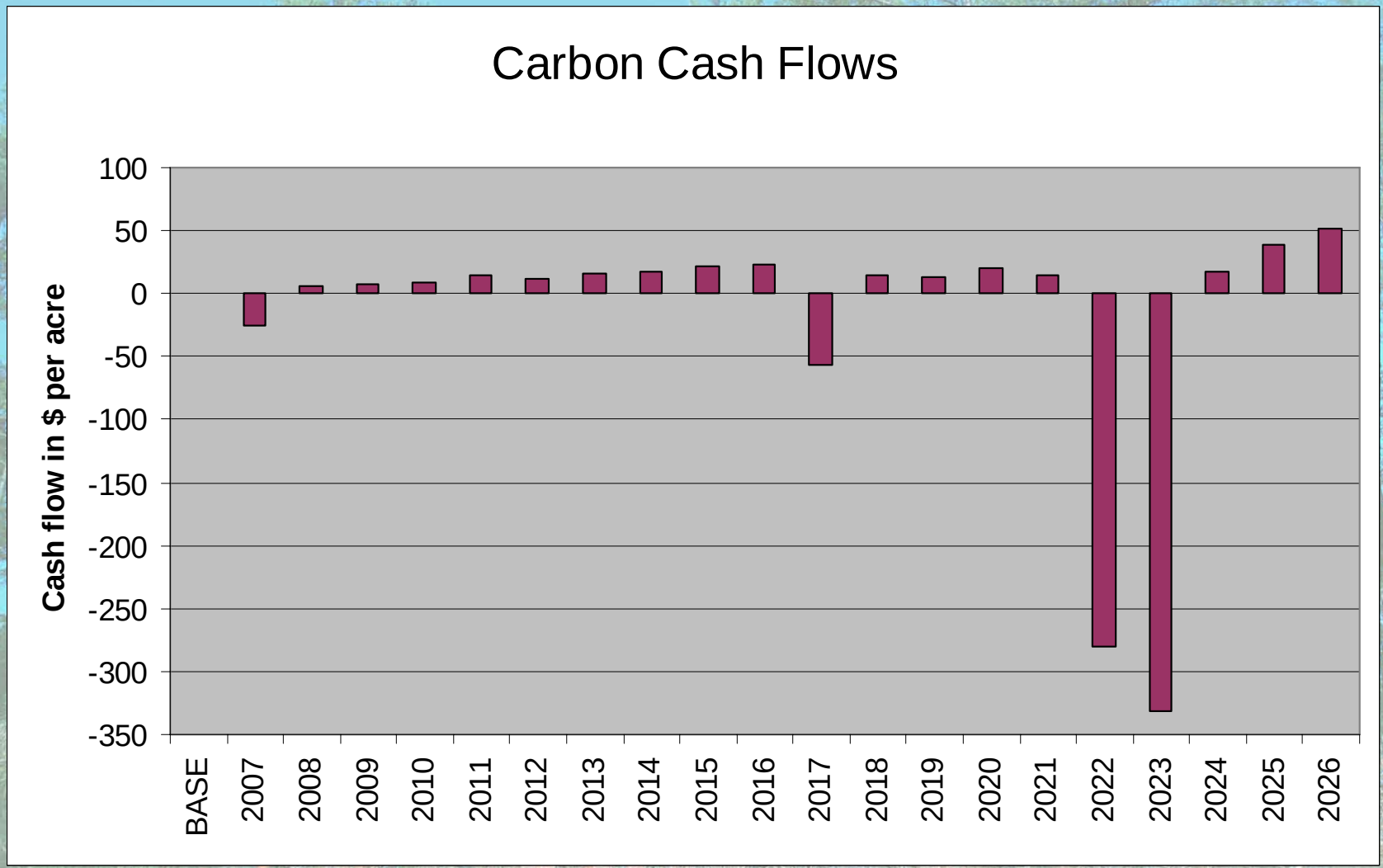
Active management regime

- Harvest 28.8 tons pulpwood per acre immediately (thin from below to 70 $ft.^2$)
  - Net cash flow of $288 per acre
- After 10 years, harvest 50 tons of chip-n-saw, and 46 tons of sawtimber
  - Net cash flow of $4665 per acre
- After 15 years, clearfell the stand
  - 28 tons of CNS, 60 tons sawtimber
  - Net cash flow of $6145 per acre
- Site prep and regeneration in year immediately following final harvest

Carbon sequestered



Cash flows from carbon



Comparison of separate components – timber and carbon credits

Year	Net Revenue of timber only	13.48%	Net Revenue of carbon only	13.48%
BASE	($2,340)	($2,340)	$0	$0
2007	$288	$254	($25)	($22)
2008	$0	$0	$6	$4
2009	$0	$0	$7	$5
2010	$0	$0	$9	$6
2011	$0	$0	$15	$8
2012	$0	$0	$11	$5
2013	$0	$0	$16	$7
2014	$0	$0	$18	$6
2015	$0	$0	$21	$7
2016	$0	$0	$24	$7
2017	$4,665	$1,161	($57)	($14)
2018	$0	$0	$14	$3
2019	$0	$0	$13	$2
2020	$0	$0	$21	$4
2021	$0	$0	$15	$2
2022	$6,145	$813	($280)	($37)
2023	$0	$0	($331)	($39)
2024	$0	$0	$18	$2
2025	$0	$0	$39	$4
2026	$1,400	$112	$52	$4
		($0)		($37)

Land and timber rate of return over 20 years is 13.48%

At 13.48% cost of capital, present value of carbon credits is negative! Carbon program will reduce income by ~$37 per acre

15-year carbon contract

Year	Land Value	Carbon Trading Reciepts	Timber Cash Flows	Net Revenue Timber + Carbon	13.59%	13.48%
BASE	-$1,400		($940)	-$2,340	($2,340)	
2007		-$25	$288	$263	$232	($22)
2008		$6	$0	$6	$4	$4
2009		$7	$0	$7	$5	$5
2010		$9	$0	$9	$6	$6
2011		$15	$0	$15	$8	$8
2012		$11	$0	$11	$5	$5
2013		$16	$0	$16	$7	$7
2014		$18	$0	$18	$6	$6
2015		$21	$0	$21	$7	$7
2016		$24	$0	$24	$7	$7
2017		-$57	$4,665	$4,608	$1,134	($14)
2018		$14	$0	$14	$3	$3
2019		$13	$0	$13	$2	$2
2020		$21	$0	$21	$3	$4
2021		$15	$0	$15	$2	$2
2022			$6,145	$6,145	$800	
2023			$0	$0	$0	
2024			$0	$0	$0	
2025			$0	$0	$0	
2026	$1,400		$0	$1,400	$109	
					$0	$30

- Assume carbon contract for 2007-2021
- Overall rate of return increases to 13.59%
- Value of carbon contract at 13.48% cost of capital is $30 per acre in today's terms

Summary and conclusions

- These examples include sequestered carbon in forest products and landfills and carbon in the forest floor and dead belowground carbon
- If forest floor carbon and belowground dead carbon is credited, intensive site prep work will have negative impact on carbon credits
- In stands that receive intermediate thinnings, carbon credits may cost you cash returns

Summary and conclusions

- Stands that are “left to grow” may show improved returns from carbon credit programs
- Timing of entry and exit into carbon programs affects returns
- FVS model is accepted by CCX to project biomass and carbon stocks in working forests.