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Pasture Management for Optimum Return

Ed Rayburn, *Extension Specialist*
WVU Extension Service, Agriculture and Natural Resources
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Optimizing returns from pasture includes managing the harvest of sunlight through forage production and managing the utilization of that forage with a grazing animal to produce an animal product that has a market value. This is a complex task but relatively easy to accomplish once the manager understands the underlying biological principles and gains experience. Optimum management results in the highest net return to the producer; usually best expressed in dollars per acre. Let's review some of the basic principles affecting pasture-based livestock production and how management can move toward gaining the optimum return.

Law of diminishing returns

The law of diminishing returns states that when an input is limiting production as more of that input is used there is less additional production for each unit of input up to a critical value beyond which there is no further response (Figure 1). In pastures we manage a number of biological systems that respond in this manner. For the whole system to function at an economic optimum the manager must balance labor, timing and intensity of grazing, and purchased inputs based on their economic response. A list of pasture management inputs and their critical value are listed in Table 1. When an input is at or above its critical value that input will not limit production in the system.

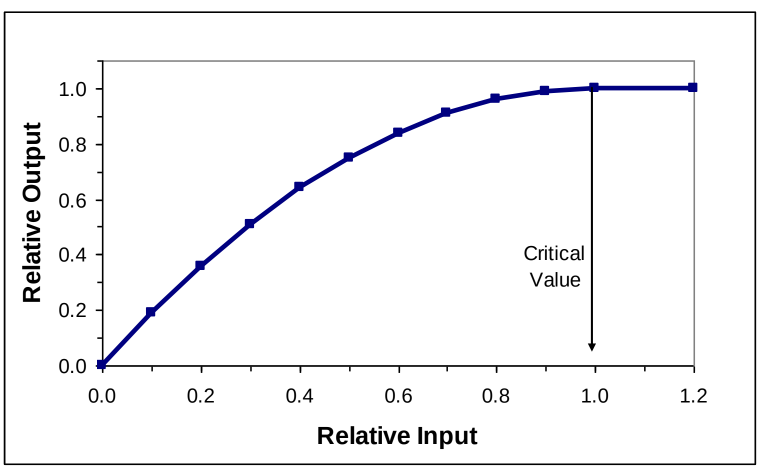

Figure 1. Law of diminishing returns. When an input limits production, output increases at a diminishing rate per unit input up to a critical value beyond which there is no further increase in production.

Table 1. Pasture management inputs and their general critical values when managing cool-season grass legume pastures.

Input	Critical value	Note
Soil Fertility		
Soil pH	6.0 - 6.5	6.0 for clovers and 6.5 for alfalfa
Soil test P	H-	Soil test index numbers for P and K depend on soil test extraction method, how the extract is evaluated, and correlation with field experiments
Soil test K	H-	
Pasture Canopy Management		
Continuous stocking		
Average forage mass	1200 lbs. DM/acre (3-4 inches)	Depends on livestock class, production goals, and forage species
Rotational stocking		
Grazing stay	Days on a paddock	Relative growth Depends on degree and timing of defoliation
	0.5	100
	1	90 to 99
	3	80 to 96
	7	70 to 90
	Continuous	45 to 50
Initial Forage mass	2400-3000 lbs. DM/acre (8-10 inches)	Depends on pasture forage density and species
Residual forage mass	800-1000 lbs. DM/acre (2 inches where grazed)	Dry mature cows or when managing for high legume content or weed control
	1200 lbs. DM/acre (3-4 inches where grazed)	Finishing steers, high milk production/cow, and other times when allowing selective grazing
Legume content	25-30% forage DM or more	Depends on available soil organic N for yield and management for bloat

Match forage species with soil and management

Forage production is determined by soil type, soil fertility and pH, mixture of plant species, grazing management, season, and weather (Table 2). Producers should start with what they have and take relatively small steps to improve their system. When planning to renovate the forage species in a pasture the new forage mix should be tailored to soil drainage and the soil limed to the pH required by the legume in the mix and properly fertilized. The grazing management (rest interval and defoliation intensity) needs to be controlled to meet the needs of the new forage species in the paddock. If these new management practices are not adhered to the pasture will most likely revert back what was previously there within a short time.

Soils differ in yield potential. Deep well drained soils with a good water holding capacity have a high yield potential. Shallow soils due to depth to bedrock or a seasonal high water table will tend to have a lower yield potential. A NRCS farm plan provides a map showing what soils are on the farm and where they are located. The WVU-ES Fertility Recommend Tool has a table listing the expected yield under good management for soils in West Virginia. Soil testing, application of needed fertilizer, lime and proper grazing management will allow the forage crop in the field to achieve these expected forage yields.

Forage species differ in average yield and yield variability (Table 3). Alfalfa has the highest yield potential if the soil is deep, well drained, and soil pH is greater than 6.5. However, on soil that is shallow, poorly drained, or with a pH of 6.0 or less red clover can be as long lived and productive as alfalfa. Average yield is important but yield variation or standard deviation (SD) is just as important when it comes when assessing production risk. The SD tells us that 2-out of 3 years yield will be within the range from 1-SD below to 1-SD above the average. The SD also tells us that 1-out of-6 years yield will be less than 1-SD below average and 1-out of-6 years yield will be greater than 1-SD above average. The SD tells us our odds. This is useful to farmers who admit that they are gamblers and want to know the odds as well as the average. The coefficient of variation (CV) is the SD divided by the average and is a measure of the relative variability in yield. Alfalfa growing on good soils has the lowest CV (0.19, Table 3) due partly to a high average yield and due partly to a low SD.

Grazing management determines how well a forage species produces or survives in a new pasture seeding. Alfalfa and red clover require a rest interval that allows the plant to come into late bud to early flower growth stage. Legumes benefit from close grazing that reduces the grasses competition for light. White clover and Kentucky bluegrass tolerate continuous grazing but do even better under rotational grazing.

When using rotational grazing use a paddock size that will be grazed off to the desired residual forage height in seven days or less. Three days is better than seven and one day is better than three. A seven day stay may be optimal for a cow-calf herd while one-half day optimal for lactating dairy cattle. To optimize production per acre when legumes provide the nitrogen grazing to a 2-inch residual height is preferred in cool weather. During hot weather (day time highs in the 90s) leaving a higher residual height reduces stress on the cool-season forages.

Table 2. Forage species characteristics, best management, and ecological adaptation.

Forage species	Growing point	Aftermath reproductive growth	Establishment vigor	Plant type	Management adaptation			Optimum soil pH	Tolerance to poor drainage	Tolerance to flooding	Tolerance to drought
					Hay	Grazing					
						Rotational	Continuous				
Legumes											
Alfalfa	Elevated	Yes	Medium	Bunch	E	E	P	6.5-7.0	P	P	E
Alsike clover	Elevated	Yes	Medium	Bunch	P	G	P	5.8-6.5	E	P	P
Birdsfoot trefoil	Elevated	Yes	Low	Bunch	E	G	G	6.0-6.5	E	P	G
Lespedeza, Korean	Elevated	Yes	Medium	Bunch	G	G	G	5.8-6.5	G	P	G
Lespedeza, Sericea	Elevated	Yes	Low	Bunch	P	G	G	5.8-6.5	G	P	G
Red clover	Elevated	Yes	High	Bunch	G	G	P	5.8-6.5	G	P	G
White clover	Ground	Yes	Low	Bunch	P	E	G	5.8-6.5	E	P	P
Grasses											
Bermudagrass	Elevated	Yes	Medium	Sod	G	G	G	5.8-6.5	P	P	G
Bluegrass, Kentucky	Ground	No	Low	Sod	P	E	E	5.8-6.5	G	G	P
Bromegrass, Smooth	Elevated	Joints	Medium	Sod	E	G	P	5.8-6.5	G	P	E
Orchardgrass	Ground	No	Medium	Bunch	E	E	G	5.8-6.5	G	P	G
Ryegrass, Perennial	Ground	Yes	High	Bunch	G	G	P	5.8-6.5	P	P	P
Ryegrass, Annual	Ground	Yes	High	Bunch	P	G	P	5.8-6.5	P	P	P
Reed canarygrass	Elevated	Joints	Low	Sod	E	G	P	5.8-6.5	E	E	E
Tall Fescue, E+	Ground	No	Medium	Bunch	G	G	G	5.6-6.5	E	E	E
Tall Fescue, E-	Ground	No	Medium	Bunch	E	E	P	5.8-6.5	E	E	G
Timothy	Elevated	Joints	Medium	Bunch	E	G	P	5.8-6.5	G	P	P

E+ - endophyte infected
E- - endophyte free

E - Excellent G - Good P - Poor

Table 3. Average, standard deviation (SD)[1] and coefficient of variation (CV)[2] of forage production for cool-season forages in the VA, WV, PA, and KY.

Species or Mixture	Site years	Average yield tons/acre	SD	CV
Legumes				
Alfalfa	122	6.23	1.18	0.19
Red clover	46	4.35	1.47	0.34
Grasses				
Orchardgrass	67	4.81	1.23	0.25
Perennial Ryegrass	25	3.58	1.39	0.39
Reed Canarygrass	36	4.78	1.46	0.31
Smooth Bromegrass	35	4.39	1.08	0.25
Tall Fescue	55	5.05	1.38	0.27
Timothy	54	4.25	1.24	0.29

1. One SD above and below the average is the range that includes 66% of the observations.
2. The CV is the ratio of the SD to the average here expressed as a decimal.

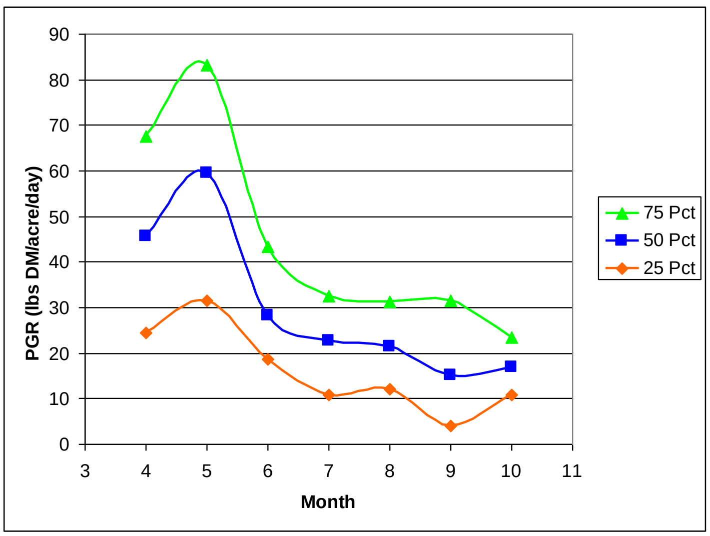

Figure 2. Pasture growth rate (PGR, in dry matter {DM}) for cool-season pastures in Morgantown WV by percentile (Pct) ranking as measured over seven years.

Production varies over the year

Cool-season forages fluctuate in growth over the year having a high growth rate in the spring and a lower growth rate in the summer (Figure 2). This occurs since cool-season forages grow best when they have long days, relatively cool weather, and moist soils. These three environmental conditions are most likely to be optimum in May and June when the days are at their longest but the weather is still fairly cool, and spring rains are keeping the soil moist.

Buffers are needed in pasture systems

Due to differences in forage growth rate over the year all pasture systems need to have one or more buffers. Buffers are used to balance livestock feed demand with available forage. Buffers include:

- Timing the livestock production cycle to the forage production cycle.
- Making hay from excess production and grazing aftermath growth as needed.
- Using strategic nitrogen fertilization during good growing conditions to stockpile forage for use during slow growth.
- Varying the stocking rate by selling or moving some animals off pasture to feedlot.
- Using warm-season and cool-season forages to help even out forage production.
- Feeding supplemental forage or other feeds grown on the farm or purchased.
- Wasting forage.
- Accepting changes in animal rate of gain or body condition.

If a buffer is not planned and managed forage will be wasted or overgrazed and animal production goals will not be meet.

Production varies from year to year

Forage production varies from year to year due to weather patterns. In Table 3 this was represented in the SD or CV the range about the average that accounts for 66% of the years. In Figure 2 it is represented by the 25 percentile line below which pasture growth rate occurs 25 percent of the time and the 75 percentile line above which the pasture growth rate occurs 25 percent of the time. Variable forage production can cause variation in animal performance and enterprise net return if management is not flexible to meet the plant and animal needs.

Diversity part of the pasture portfolio

So there is variable production that affects a pasture-system. This includes seasonal differences in climate, annual variations in rainfall, and variations in soil fertility, pH, and drainage across each pasture. Such variability affects all types of farming. However, a pasture manager has to respond to variation in real time; while a confinement manager responds to the cumulative variation at the end of the growing season.

Production variability and risk can be reduced by farm diversity. This is similar to having a diversified investment portfolio. Diversity can be accomplished by using mixtures of forage species within paddocks to optimize yield from the soil and reduce yield variability or different forages or mixtures may be used in different fields to take advantage of different soils (deep alfalfa soils versus shallow clover soils) or cool-season versus warm-season forages to balance seasonal forage needs. Diversity should be viewed at the whole farm scale and the within field scale. The biological principle is to use forage species from different ecological functional groups such as:

- deep rooting species that access water from lower in the soil,
- fibrous rooting and rhizome forming species for sod development,
- cool-season species for cool-season production,
- warm-season species for warm-season production,
- legumes to fix nitrogen and to increase forage quality
- species adapted to poor drainage or to droughty soils as needed.

Having a diversity of livestock types also helps reduce risk. One example is running stocker cattle with a cow-calf herd. The stockers help use excess forage in the spring and can them be moved to a feedlot when grass growth slows down, leaving more acreage to meet the needs of the cow herd. Calves can be early weaned and sold to reduce feed requirements in a drought year.

<u>Gain per head versus gain per acre</u>

Another pasture management principle is that there is always a tradeoff between gain per head (GPH) and gain per acre (GPA). As stocking rate is increased GPH will decrease but GPA increases up to a point where GPA plateaus then decreases (Figure 3). As SR increases the available forage has to be shared between more animals so each one has less to eat and gains less weight. However, at a low SR the gain on the next animal added to the pasture is greater than the reduced GPH from the other animals in the pasture so that the total GPA is increased.

<u>Optimizing cow-calf stocking rate</u>

For a given farm the optimum SR depends on many factors. These include forage productivity, animal size and production state (dry, growing, lactating), production costs, and value of animals or milk sold. With experience a pasture manager can learn how to optimize the stocking rate for a given class of animal on the pasture. Here is a real world example from a cow-calf herd in West Virginia (Figure 3).

The cow herd on this farm was reduced to 20 head on 90 acres due to a major drought. Over the next four years the herd was built back up using heifers produced from the herd. After weaning, heifer calves were raised on another farm so were not part of the SR. Bred heifers were returned to the farm in the fall before having their first calf. Cull cows were removed from the farm about when bred heifers were returned. Calves were sired by one bull for three years and a similar bull in the fourth year. The 90 acres provided all the pasture and hay for the herd. Protein supplements for the cows and energy supplements fed to calves during a 42-day preconditioning phase before sale were purchased. Calf sale weights were adjusted for birth date and shipping date differences between years.

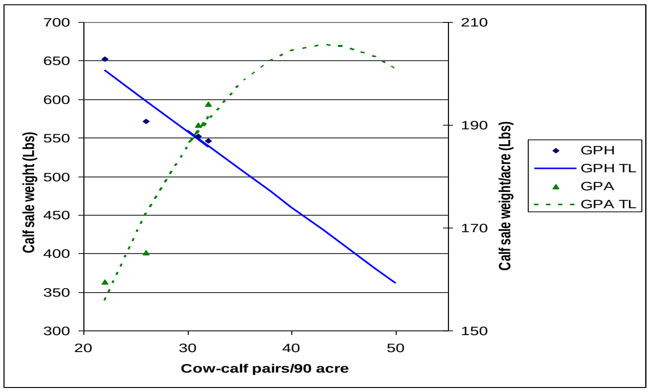

Figure 3. As stocking rate on this cow-calf operation increased gain per head (GPH) decreased and gain per acre (GPA) increased, plateaus, then decreases; trend lines (TL) past the range of observed data are used to estimate the higher stocking rates.

Average calf sale weight was plotted against cow-calf pair stocking rate on the 90 acres. The farmer used MS-Excel to plot the data but he could have used a pencil and graph paper. Since he used Excel he had the computer plot the linear trend line and calculate the relation between SR and GPH. If he had used graph paper he could have estimated the straight line relating SR to GPH.

Since GPA is simply GPH time SR the farmer made this calculation in a column beside his SR data. Using graph paper and a hand calculator the same could be done plotting the reading the GPH value from the graph, calculating the GPH times SR product, and plotting it on a second vertical axis on the right.

The following relation between SR, GPH, and GPA were found to exist over this four year period (equations 1 to 4). The regression R^2 is a measure of the fraction of variation accounted for by the SR (independent variable)

1. GPH = 854 - 9.85 SR $R^2 = 0.87$
2. GPA = GPH SR / Acres
3. GPH = (854 - 9.85 SR) SR/Acres
4. GPA = (854 SR – 9.85 SR^2) / Acres

Using equation 4 (Figure 3) we find that the biological optimum for this farm is about 43 cows producing 427 lb calves. The farmer had other records that enable him to evaluate the economic optimum. The cash cost for maintaining a cow was about $70/head, the opportunity cost for adding a cow was about $70/head/year, and the cash cost for producing the calf was about $30/head for a minimal cash cost of $170/head. In 2009 the price for calves of all weights was $100/cwt. Using these numbers to calculate gross value of the calves and net cash margin (Table 4) we find that the optimum economic stocking rate is 35 cow-calf pairs for the 90 acre farm. However, if the farm were stocked at 30 pairs net margin would be reduced by only $219. By reducing the stocking rate 14% we reduced the net margin by only 2% (Table 4). This a small price to pay for the insurance of extra forage to get though a dry year.

Table 4. Economic calculation of the stocking rate effect on projected calf sale weight, gross value with all calves worth $100/cwt, net margin when cash cost is $170/cow-calf pair, net margin/acre, and relative margin and stocking rate expressed as a fraction of the value at the optimum stocking rate of 35 cow-calf pairs/90 acres.

Stocking Rate	Projected Calf Sale Wt.	Gross value	Cash cost	Net margin	Acre /pair	Net Margin /acre	Relative Net Margin	Relative Stocking Rate
20	657	$13,140	$3,400	$9,740	4.50	$108	0.82	0.57
25	608	$15,194	$4,250	$10,944	3.60	$122	0.92	0.71
30	559	$16,755	$5,100	$11,655	3.00	$130	0.98	0.86
35	509	$17,824	$5,950	$11,874	2.57	$132	1.00	1.00
40	460	$18,400	$6,800	$11,600	2.25	$129	0.98	1.14
45	411	$18,484	$7,650	$10,834	2.00	$120	0.91	1.29
50	362	$18,075	$8,500	$9,575	1.80	$106	0.81	1.43

The calf market will affect the economic optimum. Historically, corn has been relatively inexpensive and lighter calves have been worth more than heavier calves. In such a case there is increased value in selling more light weight calves. However, pushing the stocking rate too high can have a negative impact on cow body condition and conception which will increase cow culling or percent of calves born or both. Stocking rate and cow genetics are near the optimum when cows at the beginning of winter feeding and at calving are in a body condition score of 6 without significant supplemental feeding.

Stocking rate and risk aversion

Producer aversion to risk as well as livestock production and market variability plays a part in determining the economic optimum stocking rate (SR) for a farm. Monte Carlo models (gambling or risk models) can measure the effect of variation in forage production and SR on animal performance and enterprise net return. Using an estimate of the mean and variability of forage production, obtained from farmer experience or from regional research trials, these models estimate the probability of net income being above a minimum level acceptable to the manager. The economic optimum SR can be defined as the SR that maximizes long term net income with minimal risk of net income dropping below a defined minimum in any one year.

Let’s take an example of risk evaluation using custom grazing 700 lbs. steers in conjunction with a commercial hay operation. The farm has 14 paddocks, half of which are cut for hay in early June (northern WV, 2000 ft. elevation) with all of the acreage grazed during the summer. Forage production is based on orchardgrass average yield and SD, using a range of SR, and pasture quality of 65% TDN. Animal GPH was calculated using National Research Council beef equations. Forage mass at the start of grazing is used to calculate dry matter intake as affected by forage mass. Hay is sold at market value, based on a 10-year price-supply function observed in West Virginia. Hay production costs used were $20/acre to mow and rake and $17/ton to bale. Animal gain is sold at $0.25/lbs. as custom grazing. Animal production costs are

$20/acre for pasture maintenance and $10/head for labor and supplies. With higher price for fuel, fertilizers, hay, and cattle absolute values will differ but the principle will stay the same.

Predicted GPH and GPA are presented in Figure 4 for the average (mean) and for the 15% and 85% probability levels. These probabilities are essentially 1-SD above and below the average and represent 1-in-6-years being lower than the 15% level or higher than the 85% level. The space between the 15% and 85% probabilities represents a 2-in-3-year probability region. Average GPH response to SR is similar to that seen for the cow herd. The low and high probability bands give additional information on the effect of SR on system profitability and risk. The optimum, mean GPA occurred at a SR of 1.25. However, the optimum SR at the 15% probability GPA was near 0.5. Mean net income to land, labor, and management (NLLM) occurred between a SR of 1.25 and 1.5 head/acre; resulting in more years having NLLM above the $80/acre base line value set by the manager needed to meet overhead costs.

As SR increases from low to high, variability in GPA and NLLM increases. In good years there are sufficient animals to use the increased production and they perform well. In poor years there are too many animals and GPH and GPA are lower than normal and NLLM suffers. At SR below 1 little risk-management is necessary but the producer forfeits potential production that occurs in better years. In this example on average this is $10/acre which could be looked at as an insurance payment against a drought year. Beyond a SR of 1, increased risk management plans should be developed to cover production shortfalls in bad years.

This example shows the danger of having high overhead costs such as taking on too much debt. With high overhead costs the base line NLLM per acre increases leaving less room for error in bad years. In this example at a SR of 1, a NLLM of $110/acre, and a base need of $80/acre there is a good marginal return. If the base need increased to $100/acre one time out of 6 years the owner would have to come up with money outside of the custom stocker cattle/hay enterprise to cover overhead costs.

Conclusion

Economic risk can be reduced by having planned diversity of adapted forages across the farm and within the paddocks, by having planned flexibility in moving livestock within and off of the farm, by managing the forages and livestock appropriately based on life cycle stages, and by having planned buffers in the system. Keeping simple farm records on stocking rate, animal performance, value of animal production, and input costs allows the manager to estimate the local economic optimal SR using simple tools such as graph paper or a computer spread sheet. It is important to control and minimize overhead (fixed) costs to reduce the economic risks that occur due to major weather or market changes. By using these biological and economic principles the pasture manager can optimize returns from pasture-raised livestock.

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B

C

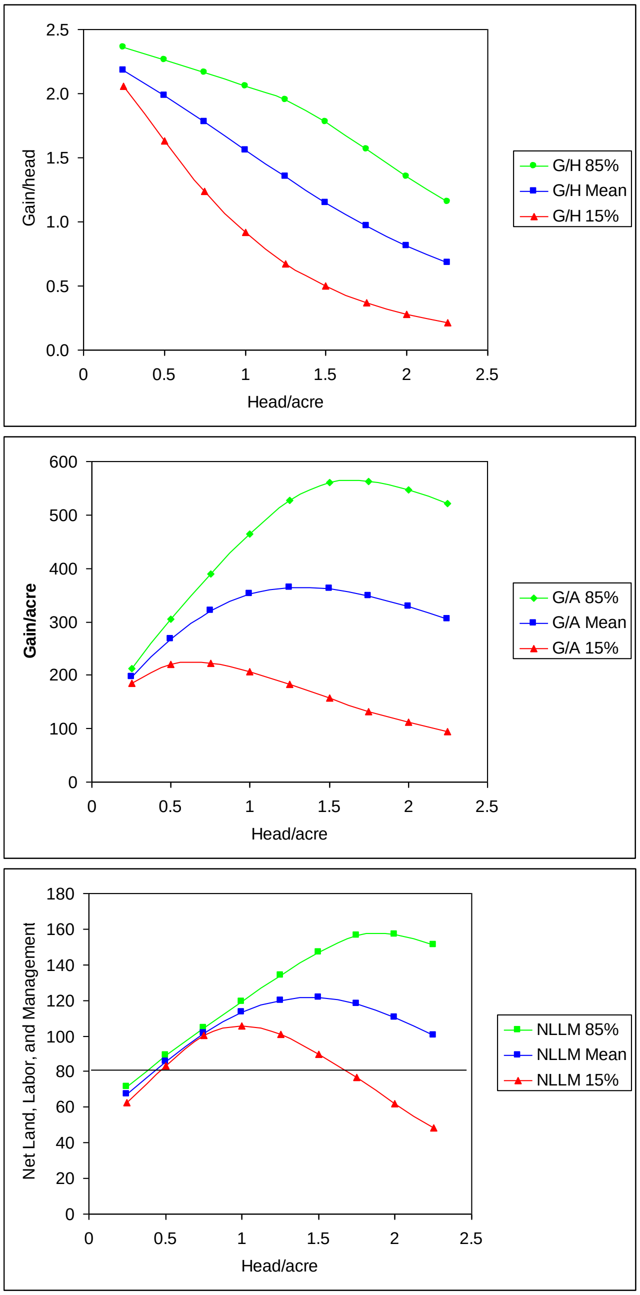

Figure 4. The effect of stocking rate on mean and 15% and 85% probability of gain/head (A), gain/acre (B) and net income to land labor and management (NLLM) (C) for a custom grazing/orchardgrass hay system in West Virginia.