1. SUMMARY

In overcoming distribution expenses associated with multi-crop vegetable farming in Colorado, a trend towards urban farming has become evident. While such farms are located within easy reach of consumers, they tend to be confined on small plots that create challenges with achieving financially sustainable "micro-farming" operations. Winter production using high tunnels is a method for increasing annual yields of specialty crops such as vegetables that is growing in popularity among Colorado farmers. This research trial primarily examines the question of how much of the cultivatable space used during the main season in an urban micro-farming operation also needs to be dedicated to fall and winter production to make the entire operation sustainable. Preliminary results of this trial indicate that the successful production for direct marketing of multiple, cold-tolerant vegetable crops during fall and winter months using a high tunnel in an urban micro-farm setting is possible, albeit with region-specific challenges. An assessment of how winter production can be conducted in order to minimally impact the yields obtained during the main season revealed that envisioning one extended season was most practical for planning purposes. In addition, an assessment of how much space is necessary to dedicate to winter production to make the entire farming operation sustainable revealed that a ¼ acre of cultivation space with half under tunnel cultivation, and the use of intensive intercropping techniques, are all factors required for a micro-farming operation to be financially sustainable.

2. MATERIALS AND METHODS

This research trial was conducted at the HeartEye Village CSA farm in Lafayette CO beginning August 1, 2011 and ending January 15, 2012. The CSA is the pilot study farm for Landshare Colorado's Grow Your Own CSA Co-op, a web-based clearinghouse of information that assists prospective beginner urban farmers in setting up farming operations. This pilot study is a peri-urban, quarter-acre, bio-intensive micro-farm CSA that provides a testing ground on 4368 sq ft of cultivatable space for co-op promoted methods.

Key personnel conducting the work for this research trial include Project Manager, Tracy Sweely, who has been the Farm Manager at HeartEye Village CSA for 3 years. A Farm Intern also assisted with conducting the work during this research trial. Justin Domingus was the Intern from August through September and Leslie Vornholt was the Intern from October through January.

The Farm Intern was responsible for soil preparation, seeding, watering, monitoring, crop maintenance, harvesting, harvest record keeping and CSA box preparation. The Project Manager was responsible for coordinating production activities, overseeing the tasks of the Intern, as well as administering the CSA, monitoring and assessing harvest data with projected harvest goals, and analyzing financial records. The Project Manager was also responsible for protocol development and information dissemination based on results of the project, and writing the Annual and Final Reports for the Project.

A Clearspan brand high tunnel used for winter production in this research trial was purchased from Farmtek under a Natural Resources Conservation Service grant awarded in early 2011. The 30' x 36' tunnel was constructed over a portion of the HeartEye Village CSA farm plot during the summer months in 2011. The tunnel was oriented lengthwise from north to south in order to best buffer the tunnel against extremely high winds common at this farm. The tunnel covered an area of 1080 sq feet and contained 606 sq ft of cultivatable space.

Multi-crop winter production plans for a winter Community Supported Agriculture program for this study were made using the Fantastic Farm and Garden Calculator (FFGC). The FFGC is a web-based application available to Grow Your Own CSA Co-op members to manage planning, implementation and monitoring of the annual production of multiple crops for a specific number of consumers and/or to fulfill specific market sales goals. The FFGC predicts production yields cultivated under average growing conditions for three skill-levels: Beginner, Intermediate and Advanced. The Beginner Skill Level was used for this research trial. An overview of how the FFGC works can be found in **Appendix A**. A short tutorial video for using the FFGC can be found at: http://www.youtube.com/watch?v=BPCW1Msw3T0. It is strongly recommended that the reader become familiar with the functionality of the FFGC tool prior to reading this report.

Since it was not designed to account for the increased maturation time anticipated for winter production, planting and harvest dates generated were considered suspect. But yield projections were thought to be sound and achievable thus the plan was used as a model against which yield data collected during this research trial was measured.

The FFGC-based plan during winter production included providing $250 worth of produce to each of 9 CSA Half-Shareholders over the course of 12 weeks during the months of October through December, and to generate $614 from additional retail market sales during the same period. Retail sales were through the HeartEye Village CSA Farm Stand and the Virtual Farm Stand; a weekly, e-mail based produce-ordering system offered to consumers.

The cultivation space under the high tunnel was prepared and planted beginning in August 2011. The timeline for planting is based upon winter production planting date research conducted by Eliot Coleman in The Winter Harvest Handbook (2009), and took place beginning at the end of the first week of August 2011. Based on Coleman's data for winter production planting times it was calculated that all seeding should be done prior to the end of September. This was so that sufficient plant development would occur prior to day length and temperature reductions of late fall and winter and to enable continued production through the winter. The CSA harvest began the first week of October and will continue through the last week of December. Limited retail sales are also anticipated through January 2012 until all winter crops are spent.

Lettuce and Radish crops were found by Coleman (ibid) to succumb when air temperatures became consistently freezing. For this study measures were taken to attempt to grow these crops beyond this point. Thus soil heater cables were used experimentally in a row where these crops were grown, constituting 119 sq feet. The soil heater cables used were intended for keeping soil temperature around 75 degrees. But our intention was simply to keep the soil temperature above freezing and so the cables were placed on a timer and only operated for 5 hours between midnight and 5 AM.

Most crops grown in the high tunnel for winter production for the CSA were types suited for cold weather production but others included a few cold and hot weather crops held over from the main season until temperatures were too low to support them. Cold weather crops cultivated inside the tunnel and intended to comprise a majority of the total produce yield included Arugula, Beets, Bok Choy, Carrots, Chard, Cilantro, Kale, Leeks, Lettuce, Mustard, Pearl Onions Scallions, Snow Peas, Radishes, Spinach and Turnips. Varieties used were selected based on Coleman (ibid). Details about the varieties of crops cultivated in the tunnel are given in **Appendix B**. Hot weather crops held over from the main season inside the tunnel included Peppers, Eggplant, Tomatoes and Cucumbers. Some cold weather crops were also held over outside of the tunnel from the main season. These included Chard, Kale, Celery, Lettuce and Cabbage (inside and outside the tunnel). Finally, some previously harvested storage crops carried over from the main season added to the value of the CSA boxes and these included Onions, Garlic, Tomatillos and Winter Squash.

Planting dates for the cold weather crop successions cultivated inside the tunnel were as follows.

Arugula, weekly for 7 weeks, beginning August 10
Beets, weekly for 4 weeks, beginning August 17
Bok Choy, weekly for 7 weeks, beginning August 17
Carrots, weekly for 4 weeks, beginning August 10
Chard, weekly for 6 weeks, beginning August 10
Cilantro, weekly for 3 weeks, beginning August 10
Kale, weekly for 6 weeks, beginning August 10
Leeks, in one succession on June 10
Lettuce, weekly for 6 weeks, beginning August 10
Mustard, weekly for 6 weeks, beginning August 10
Scallions, 2 succession 6 weeks apart, beginning August 10
Pearl Onions, weekly for 4 weeks, beginning August 10
Snow Peas, weekly for 2 weeks, beginning July 5

Radishes, weekly for 4 weeks, beginning August 24
Spinach, weekly for 6 weeks, beginning August 10
Turnips, weekly for 4 weeks beginning August 17

All crops were direct seeded but Bok Choy, Chard, Kale, Leeks, Lettuce, Scallions, Spinach and Pearl Onions were also started in flats. We did so because we wanted to assess whether the improved germination in flats during the hot end-of-summer temperatures would positively offset the impairment they would suffer from being transplanted out. It was not known whether transplants would have sufficient time to recover during the short period of time of optimal growth before the onset of the reduced daylight hours of the fall. All crops seeded in flats were transplanted as they got their true leaves, between August 20th and September 24th.

Once nighttime outdoor temperatures began dipping below 50 degrees, all crops inside the tunnel were covered at night with two layers of ½ oz row cover. Coleman (ibid) found that row cover resting directly upon the plants caused freezing of leaves at the points of contact. To mitigate this possibility, 12" staples were evenly spaced in the rows to suspend the row cover above the plants. If daytime temperatures inside the tunnel dipped below 50 degrees one layer of row cover would be removed, otherwise both layers of row cover were removed in the morning and replaced late in the afternoon each day. When the row cover was removed it was hung off of guy-wires to dry accumulated condensation. If outside daytime temperatures exceeded 50 degrees the tunnel was manually vented in order to prevent inside temperature from exceeding 75 degrees. Venting occurred by opening the south end of the tunnel first and then opening the north end if necessary.

Watering of crops was done by hand on an as needed basis approximately once a week. Pests control measures included the regular use of Sluggo and Diatomaceous Earth for slugs and Terrad 3, commonly used in organic greenhouses for rodents such as mice and voles.

Crops were harvested on a weekly basis for the preparation of the CSA box beginning the first week of October and ended the final week of December. All harvested crops were weighed prior to dividing and distribution into the CSA boxes. Any crop yields beyond what was designated for the CSA was sold at retail market at the Farm Stand (weather permitting) or Virtual Farm Stand. Weekly harvest totals were uploaded into a spreadsheet in order to track the total harvest as the season progressed and to track the realized value of the CSA boxes.

In order to model the financial component of this research trial, a Financial Projections tool is being used. This tool is based upon a budgeting spreadsheet co-developed by Tracy Sweely and a team headed by Dawn Thilmany, PhD, at the Department of Agriculture and Resource Economics at Colorado State University. Financial records from the HeartEye Village CSA operation were drawn upon to populate expense categories of the Financial Projections tool. To populate the income categories of the Financial Projections tool, production and income projections generated by the FFGC were used. The two tools were then used to simulate farming operations. Permutations of the Financial Projections tool were examined to assess the conditions necessary for a micro-farm to achieve financial sustainability. For the purposes of this assessment, "micro-farm" is being defined as a farming operation producing for market, beyond the needs of one family, on 1 acre or less of cultivatable space. Financial Sustainability is being defined as the ability to meet all expenses of the operation as well as pay a living wage for one full-time labor position and minimum wage for necessary accessory labor.

3. RESULTS

Methods

The high tunnel was used effectively to produce and extend crops and only sustained minor damage due to high winds. A 2-foot tear in the plastic cover was observed at one corner of the structure near the ground, easily repaired with tape designed for the purpose. The heavy polypropylene end caps sustained some wear and tear near the bottom edges from cinderblocks used to weight them down during strong winds.

The method of handling the row cover used for this study was found to be highly effective in mitigating the cold temperatures and allowed the plants to thrive. It was discovered that using 12" staples to suspend the row cover above the plants did not prevent the cover from sagging between staples and thus did not always prevent the row cover from contacting the leaves. But such contact was only found to cause minor damage infrequently; only when conditions were damp enough that condensation on the row cover did not dry during the day and nighttime air temperatures were below freezing.

Once outdoor air temperature were consistently below 50 degrees, the soil heater cables maintained the minimum soil temperature within the range of 46 to 48 degrees, averaging 46.76 degrees for three weeks in November. The electricity to the soil heater cables was accidentally turned off at the beginning of December and remained off for three weeks. During this time the minimum soil temperature fell within the range of 36 to 40 averaging 39.2 degrees. During the time that the cables were off, the Butterhead Lettuce produced slowly, becoming wilted and mottled with brown spots although the Rouge D'Hiver Lettuce and the Radishes continued to produce without any associated problems.

Production Yields

The following table lists the yields realized to date by HeartEye Village CSA for each cold weather crop cultivated in the high tunnel and those predicted by the FFGC plan for the winter production conducted during this research trial:

	Total lbs harvested	FFGC Predicted Yield (lbs)
Arugula	10.38	8
Beets & Greens	3.63	41
Bok Choi	14.22	27
Carrots	0	81
Chard	.45	38
Cilantro	0	0
Kale	15.56	27
Leeks	.69	11
Lettuce, Leaf and Head	24.82	108
Mustard	33.64	27
Onions, Pearl	0	
Onions, Scallion	1.21	
Radishes	85.75	81
Spinach, green	8.27	54
Turnips	36.12	27

Cold weather crops cultivated in the tunnel that produced as expected included Arugula, Mustard, Radishes, and Turnips. A large portion of the Mustard yield was due to volunteer plants from the main season discovered inside the tunnel. Cold weather crops cultivated in the tunnel that produced less than expected included Beets, Bok Choy, Carrots, Chard, Cilantro, Kale, Leeks, Lettuce, Pearl Onions, Scallions, Snow Peas, and Spinach. It was observed in the first few weeks of seeding that the density of Spinach, Bok Choy and Kale was lower than expected by approximately 75% for the former and 50% for the latter two. There were significant germination issues with Beets, Carrots, Cilantro and Snow Peas. Beets germinated well, but pests immediately consumed the small seedlings prior to the application of pest control substances. Carrots and Snow Peas did not germinate until the beginning of October. Cilantro did not germinate at all. All varieties of Lettuce except for Rouge D'Hiver and Butterhead had been intercropped with early successions of Radishes and were crowded out. It was also noted that of the cold weather crops that were seeded in flats Bok Choy, Lettuce, and Kale continued to develop at a fast pace after transplanting, but Scallions, Pearl Onions and Chard grew slowly, never developing to maturity.

Hot weather crops carried over from the main season inside the tunnel that did well until temperatures inside the tunnel dropped below what was necessary for their continued production were Basil, Cucumbers and Tomatoes. Basil was harvested until October 20th and Cucumbers and Tomatoes until October 27th. Hot weather crops carried over from the main season in the tunnel that did not do well were Peppers and Eggplant. Both of these crops had been intercropped during the main season and unfortunately, overlooked crowding stunted their development. They did not start flowering until well into September and rodents ate the few small fruits that were produced.

Cold weather crops carried over from the main season outside the tunnel all did well until outside temperatures dropped below what was necessary to support them. Lettuce and Cabbage were harvested until October 20th and Kale and Chard were harvested until November 10th. In addition, storage crops from the main season stored well through December with no losses.

The following table lists how many lbs of each crop each CSA member has received to date. Also included is what the value of those amounts were for each crop, as well as the total realized value of the share, based upon average prices charged for organic farm produce sold in the region. Prices in italics are estimates based on similar crops.

	oz/person	**lbs/person**	**Ave $/lb**	**1/2 shr bx val**
Arugula	18.83	1.18	10.67	12.56
Beets & Greens	7.25	.45	2.79	1.26
Bok Choi	26.27	1.64	1.60	2.63
Cabbage	8.00	0.50	2.00	1.00
Carrots	0.00	0.00	2.05	0.00
Chard	11.27	0.70	2.93	2.06
Cilantro	2.25	0.14	*18.70*	2.63
Garlic	0.70	0.04	*10.00*	0.44
Kale	20.40	1.90	3.24	6.16
Leeks	1.3	.04	2.85	0.23
Lettuce, Leaf and Head	59.76	3.74	8.00	29.88
Mustard	52.45	3.28	*8.00*	26.23
Onions, Red	11.74	0.73	1.70	1.25
Onions, Yellow	12.81	.80	1.70	1.36
Peas, Snow	0.00	0.00	8.00	0.00
Radishes	106.28	6.64	2.00	13.29
Spinach, green	14.45	.90	6.73	6.08
Turnips	63.50	3.97	3.00	11.91
Turnip Greens	0.00	0.00	3.24	0.00
Basil, Green	1.00	0.06	18.70	1.17
Beans, Yellow	4.96	0.31	2.80	0.87
Beans, Green	4.00	0.25	2.80	0.70
Cucumber	35.48	2.22	1.97	4.37
Eggplant, Japanese	4.00	0.25	2.58	0.65
Eggplant, Black	9.00	0.56	2.58	1.45
Melons	85.60	5.35	0.90	4.82
Peppers, Bell	7.39	0.46	2.30	1.06
Peppers, Aneheim	4.28	0.27	3.20	0.86
Peppers, Jalepeno	0.75	0.05	3.20	0.15
Summer Sq, Patty Pan	8.00	0.50	1.65	0.83
Summer Sq. Crookneck	16.00	1.00	1.65	1.65
Summer Sq Zucchini	12.00	0.75	1.65	1.24
Tomatillas	14.78	0.92	4.69	4.33
Tomatoes, Cherry	39.75	2.48	4.50	11.18
Tomatoes	77.60	4.85	3.46	16.78
Winter Sq.	60	3.75	1.25	4.69
Celery	2.00	0.13	*1.00*	0.13
Total				**175.84**

The total amount sold at retail market via the Farm Stand and the Virtual Farm Stand is $272.40.

Coordination of Main Season and Winter Season Planning

For winter production for this study a different version of the FFGC plan was used for the winter season than was used for the main season. These two plans can be found in **Appendix C**. One reason for using two separate plans was that winter planting and harvest schedules diverge significantly from that of the main season.

Upon analysis of the production results from this study it was found that the most practical way to coordinate the main season and winter season planning was not to envision two separate seasons but rather to envision one season extended at both the beginning and end by the presence of the tunnel. Because "climate conditions" inside the tunnel are so different from that outside the tunnel, a different plan would need to take place for each location. Specifically the plan for inside the tunnel would have a much earlier frost date and a much later production end date than outside the tunnel.

The FFGC was originally designed for main season production only. But the tool can effectively be used for the type of planning indicated here. Four FFGC production plans were created that account for variation in production cycles inside the tunnel and outside the tunnel while simultaneously accounting for market type. Many combinations of market types could be made, but since this study focuses on the urban micro-farm CSA, the CSA plan is central in this discussion with market sales being included but less germane.

Prior to creating the four plans, an assessment of the total amount of each crop to be produced for the CSA must be made. Given the price of a CSA share that the market in the region will currently bear, the amount of produce provided to CSA members should be viewed as supplementing their regular diets rather than composing a significant portion. **Appendix D** contains two **Box Value** spreadsheets that can be used to calculate the regional value of a CSA share. If retail prices for crops are unknown, average prices for crops are calculated based on user inputs of prices charged by neighboring farms or at local farmer markets. Then the number of lbs of produce that each CSA member will receive over the course of the season is input for each crop. Once the spreadsheet is completed, the value of the box is calculated in the lower right corner of the sheet. This value should be an amount that members are willing to pay or amounts will need to be adjusted. The amount of each crop is then used for completing the FFGC plans for production. The spreadsheets in **Appendix D** are already completed based on produce amounts found to be both achievable at HeartEye Village CSA and commensurate with member expectations. The first sheet is for a $450 half-share (1 person) and a $900 full-share (2-person), 32-week box from May through December. The second sheet is for a box with the same specifications but with content valued at $500 and $1000 respectively.

Of the four FFGC plans one is for production outside the tunnel and three are for production inside the tunnel. Of the three plans used for inside the tunnel one is for hot weather crops grown primarily for the CSA, another is for cold weather crops grown for the CSA and the third is for cold weather crops grown for retail sales. The plan for outside the tunnel is for specific hot weather crops grown for the CSA, and hot and cold weather crops grown for retail sales. **Appendix E** contains the following FFGC plans for a hypothetical 45 member CSA producing on a plot 100' by 200', with approximately ¼ acre of cultivatable space or 3136 row feet (42" wide), in full sun, with half of the space (1568 row feet) under tunnel cultivation:

Hot Crops in Tunnel for CSA
Cold Crops in Tunnel for CSA
Cold Crops in Tunnel for Retail
Hot & Cold Crops Outside for CSA & Retail

Hot Crops in Tunnel for CSA

While the tunnel provides season extension for all crops, hot weather crops have different dates for final harvest than cold weather crops do. The Frost Date for the **Hot Crops in Tunnel for CSA** plan is 4/18/2011, one month earlier than crops planted outside. The Garden End Date is 11/1/2011, the date at which the hot weather crops in the tunnel in the winter production phase of this study succumbed to cold temperatures. Most of the hot weather crops for the CSA are produced in the tunnel and accounted for in this plan so that these crops will be available to CSA members for as long as possible over the course of the annual production cycle.

The "# of lbs /wk per person" of each crop to be provided to each member is input in the Hot Weather Crop Inputs section of the FFGC. This amount for each crop is based upon the total amount to be provided over the course of the season used in the **Box Value** spreadsheet, in this case the first page in **Appendix D**. The amount input for each crop in the plan is calculated by dividing the total amount per person to be given in the box for each crop by the number of weeks it is to be given, so a measure of trial and error is involved. The "# of days of harvest" value generated by the FFGC is instrumental here. The input for the "# of lbs /wk per person" is correct when the total expected yield generated by the FFGC for each crop for the season equals the amount for each crop given in the **Box Value** spreadsheet multiplied by the number of CSA members. After the amounts for CSA members are input, the FFGC calculates the amount of cultivation space needed.

Once the **Cold Crops in Tunnel for CSA** plan is completed, described below, any remaining space inside the tunnel can be dedicated to production of crops for market sales. Market sales of hot weather crops are accounted for in the Hot Weather Crop Inputs section of the **Hot Crops in Tunnel for CSA** plan. Of the total 1568 row feet inside the tunnel, in this plan 570 row feet have been used for production of hot weather crops for the CSA and for market sales. Market sales for this plan are accounted for on the final page. The total amount of retail sales income from hot weather crops grown in the tunnel is projected to be $927.60.

Cold Crops in Tunnel for CSA

Dates for sowing and final harvest for cold weather crops in the tunnel are different for those of hot weather crops because the cold weather crops can be started earlier and will continue to produce for a much longer period of time. The Frost Date for this plan is 4/18/2011, one month earlier than crops planted outside. The Garden End Date is 12/31/2011, the date at which winter production was concluded for this study. All of the cold weather crop types produced for the CSA are accounted for in this plan so that these crops will be available to CSA members for as long as possible over the course of the annual production cycle.

The "# of lbs /wk per person" of each crop to be provided to each member, the number of weeks and the succession interval fields are manually populated in the Cold Weather Crop Inputs section of the FFGC. The amount for each crop is based upon the total amount to be provided over the course of the season used in the **Box Value** spreadsheet. These figures are arrived at in a manner similar to that explained for the **Hot Crops in Tunnel for CSA** plan above. Once the fields are filled in for each crop, the FFGC calculates the amount of cultivation space needed. Succession planting of crops in the same location as previous successions is automatically accounted for resulting in only 636 row feet being used in this plan. Any remaining space inside the tunnel can be dedicated to production of crops for retail sales, which is accounted for in the **Hot Crops in Tunnel for CSA** plan above and in the following described plan.

Cold Crops in Tunnel for Retail

As with the cold weather crops produced for the CSA those produced for the market sales have the same sowing and final harvest dates. But because a continuous harvest of crops is more conducive to market sales, successions are sown more frequently than for the CSA and thus a different plan is used. The Frost Date for this plan is 4/18/2011, one month earlier than crops planted outside. The Garden End Date is 12/31/2011, the date at which the winter production was concluded for this study.

The number of lbs per week of each crop to be sold, the number of weeks and the succession interval are all input in the Cold Weather Crop Inputs section of the FFGC. Once these fields are filled in for each crop, the FFGC calculates the amount of cultivation space needed. This cultivation space cannot exceed the amount of space available, i.e. the amount of space remaining after the previously described tunnel plans are completed. If the amount of space does exceed what is available adjustments to the number of lbs per week of each crop to be sold can be made. Succession planting of crops in the same location as previous successions is again automatically accounted for resulting in only 362 row feet being used for this plan. Market sales for this plan are accounted for on the final page. The total amount of retail sales income from cold weather crops grown in the tunnel is $15,936.00.

Hot and Cold Crops Outside for CSA & Retail

Since no season extension is being attempted outside the tunnel, hot and cold weather crops have the same final harvest date and therefore can be included on the same plan. The Frost Date for this plan is 5/18/2011, considered the average final Frost Date for the zone that includes Lafayette CO. The Garden End Date is 10/15/2011, the date at which outside production at HeartEye Village CSA ends, when temperatures begin to decrease below the tolerance levels for most crops.

The number of lbs per week of each crop to be sold, the number of weeks and the succession interval are all input in the Cold Weather Crop Inputs section. Hot weather crops produced for the CSA that are ranging, or do not need season extension, such as Melons and Summer and Winter Squash, are more conducive to production outside the tunnel. Of these crops the "# of lbs /wk per person" of each crop to be provided to each member and the number of lbs to be sold are input in the Hot Weather Crop Inputs section. Once these fields are filled in for each crop, the FFGC calculates the amount of cultivation space needed. Succession planting of cold weather crops in the same location as previous successions is again automatically accounted for resulting in only 1542 row feet being used with 26 row feet remaining uncultivated. Market sales for this plan are accounted for on the final page. The total amount of retail sales income from crops grown outside the tunnel is $13,325.75. The total amount of retail sales income from all four plans combined is $30,189.35, or approximately $30,190.00

Once the four FFGC plans are completed the Crop Row Information, the Crop Row Planting and Harvest Date Information and the Crop Seed Amount Information sections generated by the FFGC are used to implement production. The overview found in **Appendix A** provides more information on this process.

Financial Sustainability Simulation

For assessing the factors necessary to make a micro-farming operation financially sustainable the Financial Projection and the FFGC planning tools were used. Clearly, it is not possible to account for all variables for an "average" micro-farming operation; hence any simulation should be viewed as a type of baseline for comparison.

In addition, although the FFGC is great for managing planning complexity, it has not been extensively tested for accuracy as a yield prediction tool and so its reliability as a tool for modeling production yields is unknown. Analysis of the actual HeartEye Village CSA yield data from its first three years of operation indicate that while yield predictions for Summer and Winter Squash, Tomatoes, Cucumbers, and Beans have been consistently surpassed, that of herbs, greens and root crops have yet to be achieved. Nevertheless, the overall Box Value for main season production has been consistently surpassed each year and thus for the purposes of this study the FFGC can be used to simulate operations, with some degree of caution.

A blank version of the Financial Projection spreadsheet and instructions for filling it out can be found in **Appendix F**. On the left side of the sheet are input fields for projected financials. On the right side of the sheet are projections based upon the values in the input fields. An accessory sheet of the Financial Projections tool is called the Asset Replacement Calculator and is used for calculating the amount needed to be saved each year for the eventual replacement of capital assets.

Input fields for the Financial Projections sheet include categories for:

Amount of cultivatable space
Income during the first three years of operation for Year 1-Year 3 (Y1-Y3)
Income during the subsequent four years of operation for Year 4-Year 7 (Y4-Y7)
Capital expenses
Annual administrative expenses
Annual variable expenses

Projections for 7 years of operation based on all inputs include:

Input fields for capital on-hand, loan interest rates and cost of living rates
Projected asset replacement savings needed
Projected capital investment needed
Projected minimum cash-flow buffer needed
Projected loan payments required
Projected carry-over from one year to the next

Financial sustainability is achieved when the amount of **Capital Investment Needed** is decreasing from year to year, and the amount of each year's **Carry-over** is greater than the **Cash Flow Buffer Minimum** and is also increasing from year to year.

Two versions of the Financial Projections spreadsheet can be found in **Appendices G** and **H**. The first Financial Projection version (**Appendix G)** is filled in based upon income projected from FFGC plans and expenses extrapolated from the actual financial records of HeartEye Village CSA during its first three years of operation.

The operation reflected in this spreadsheet differs from the actual HeartEye Village CSA operation in several ways. Primarily, at the beginning of this study it was thought that the amount of cultivatable space used at HeartEye Village, 1/10 of an acre, would be sufficient along with some amount of season extension via tunnel production to make the operation financially sustainable. But it was found that even if the entire area, instead of just a small portion, were under tunnel production; the operation would still be financially unsustainable. Thus the minimum amount of cultivatable space that would allow such an operation to be sustainable was sought.

The total amount of cultivatable space used in the model in **Appendix G** is ¼ acre instead of the 4368 sq ft that HeartEye Village currently produces on. Also, instead of just one 30’ x 36’ tunnel, half of the total available cultivatable space is hypothetically under tunnel production. With the increase in yields due to a greater amount of cultivatable space and to season extension, and with the assumption that market sales channels are fully open and functioning, a greater number of CSA memberships and an increase in market sales and other types of income than that at HeartEye Village CSA, are indicated. The four FFGC production plans discussed above and found in **Appendix E** have been used with this Financial Projections spreadsheet to populate the number of CSA memberships and the total market sales income possible. 45 half-share CSA memberships are indicated at the $450 Box Value level and the retail sales for the FFGC plans total $30,190. Other types of income were conservatively extrapolated from the financial records for HeartEye Village.

In addition to income differences between the actual HeartEye Village CSA operation and the hypothetical one indicated here, there are also differences in expenses. Rather than using an intern as the primary labor force as is the case at HeartEye Village, the Management Labor expense is for a full-time Farm Manager being paid a living wage over a 10-month production season. Extrapolating the amount of labor for the methods used at HeartEye Village from 1/10 acre to ¼ acre were assumed to be impractical so labor saving methods were incorporated in two areas. First, at HeartEye Village hand watering has been done until seeds germinate at which time the irrigation system meets the watering needs of crops. The model described here incorporates a sprinkler system on a timer for germination watering. In addition, hand tilling at HeartEye Village has been replaced with rototilling in this model.

There are differences between the HeartEye Village operation and the model reflected in **Appendix G** in other types of expenses as well. Capital expense differences include three greenhouses for production of bedding plants instead of two, and of course more and larger high tunnels, along with accessory equipment. Tunnel costs are based on DIY tunnel information from Cure Organic Farm in Boulder CO, rather than on the manufactured tunnel used in this study, since the DIY tunnel was expected to cost less.

Some Capital and Administrative, and all Variable Expenses have been increased over actual expenses incurred by HeartEye Village in direct relation to the increase in cultivatable space and season extension. More refrigeration to support greater yields is also reflected. Utilities increase with the amount of space and yields. Insurance, seed, pest control costs, add-on costs as well as Working Share labor are all greater, commensurate with the increased size and scale of the operation modeled in **Appendix G**.

As you can see from the projections on the right side of the Financial Projections sheet in **Appendix G** this ¼-acre operation is unsustainable in this form. The overall trend for the amount of **Capital Investment Needed** each year is increasing. In addition, each year’s **Carry-over** does not meet the **Cash Flow Buffer Minimum** in all years and the overall trend of the **Carry-over** is decreasing.

The second Financial Projection version, **Appendix H**, reflects changes that could potentially be made to the hypothetical ¼-acre operation found in **Appendix G,** in order to make it financially sustainable without increasing the amount of cultivatable space. Such changes focus upon using techniques that increase yields without increasing the amount of cultivatable space to avoid a commensurate increase in annual labor for plot preparation. In order to achieve financial sustainability in all 7 years, retail sales would need to increase from $30,190 in the previous example to $41,700, the number of CSA members served would need to increase from 45 of 83 members and the Box Value would need to increase by $50 per CSA member from $450 to $500 for the half-share. There is very little room for divergence from this projection. In fact, even if these increases were to occur incrementally between the first 3 years of operation and the subsequent 4 years, the operation would still be financially unsustainable. In addition, permutations reflecting the entire amount of cultivatable space under tunnel production instead of just half, were also financially unsustainable since the increased yields from the meager season extension offered did not offset the initial capital investment in the increased number of tunnels.

One bio-intensive technique that is used to increase yields without increasing the amount of cultivation space is intercropping. The previously mentioned FFGC production plans found in **Appendix E** and used to populate the income sections of the previous Financial Projections spreadsheet found in **Appendix G**, do not incorporate the use of the intercropping technique. There are several types of intercropping methods but mixed intercropping, i.e. planting short, shade tolerant crops with tall crops is focused upon here. By incorporating mixed intercropping into production operations, four new FFGC production plans have been created. These plans can be found in **Appendix I** and include:

Hot Crops in Tunnel for CSA Intercrop
Cold Crops in Tunnel for CSA Intercrop
Cold Crops in Tunnel for Retail Intercrop
Hot & Cold Crops Outside for CSA & Retail Intercrop

While the sowing and final harvest dates for these plans are identical to the previous examples from **Appendix E**, the cultivation space allocation is different. Since the CSA is a more prominent focus in this analysis than market sales, the allocation difference is due to first increasing the number of CSA members to the greatest number possible as a result of the space made available from intercropping. This was done while simultaneously increasing the **Box Value** (**Appendix D**, 2nd page)

The cultivation space allocation was first altered for the **Hot Crops in Tunnel for CSA Intercrop** plan for the increase in CSA members from 45 to 83. Hot weather crops for retail sales were left as is from the previous plan. Of the total 1568 row feet in the tunnel, hot weather crops account for 974 row feet in the tunnel. Next, the **Cold Crops in Tunnel for CSA Intercrop** plan was altered, intercropping 714 row feet of the short-growing, shade-tolerant cold crops with the tallest hot weather crops. Limited intercropping of cold weather crops with other cold weather crops was also planned, accounting for 186 row feet. Along with intercropping, the succession planting of cold crops in the same location as previous successions is again automatically accounted for. Succession planting occurs in the model in both intercropped and non-intercropped locations. As a result of combined succession planting and intercropping, only 415 additional row feet have been used, leaving 179 row feet inside the tunnel. This space is put to use in the **Cold Crops in Tunnel for Retail Intercrop** plan. In addition to planting in the 179 row feet of available space, 216 row feet of crops for retail sales are being intercropped with hot weather crops in the model. Limited intercropping of cold weather crops with other cold weather crops is also planned and account for 194 row feet. The succession planting of cold crops in the same location as previous successions is again automatically accounted for.

A total of 1568 row feet are available outside of the tunnel. Since the final harvest end date is the same for both hot and cold weather crops grown outside, production plans for both can be made on the same FFGC plan. These can be found in the **Hot & Cold Crops Outside for CSA & Retail Intercrop** plan. In keeping with the CSA focus, the hot weather crops produced for the CSA that are ranging, or do not need season extension, were first increased to meet the increased number of CSA members and the increased **Box Value**. Once this was accomplished all remaining hot and cold weather crop planning was for retail sales. A total of 776 row ft of cold weather crops was intercropped with predominantly hot weather crops but with some cold weather crops as well. As described above succession planting of cold weather crops in the same location as previous successions was automatically accounted for. A total of 1543 row feet was used in this plan with 25 row feet remaining uncultivated.

Market sales for all of these plans are accounted for on the final pages of each plan. The total amount of retail sales income from all plans combines is $41,700. The input values for income in the Financial Projection spreadsheet found in **Appendix H** is supported by these plans. As you can see from the Projections section of the spreadsheet the hypothetical operation reflected in these plans is financially sustainable. The amount of **Capital Investment Needed** is decreasing from year to year, and the amount of each year’s **Carry-over** is more than the **Cash Flow Buffer Minimum** and is also increasing from year to year.

4. CONCLUSIONS AND DISCUSSION

There were three goals for this research trial. The first goal was the successful production of multiple, cold-tolerant vegetable crops during fall and winter months using a high tunnel.

Methods for production were effective. Suspension of the row cover so that it does not contact the leaves does not appear to be a necessity. Since the arid climate of Colorado allows condensation on the row cover to dry during warmer daytime temperatures, when air temperatures are sufficiently cold at night, freezing at the points of contact does not tend to occur on a significant number of the leaves. In addition, because the soil heater cables were inadvertently turned off during the coldest part of the production season an assessment of their effectiveness could be made. The cables did not appear to be necessary for Radishes and Rouge D'Hiver Lettuce but were probably necessary for the continued production of the Butterhead Lettuce.

Planting dates seemed to have been more of a determinant of success than both crop types and crop varieties used. Arugula, Radishes and Turnips that did well were all fast growing crops with less than a 40-day maturation interval. The volunteer Mustard plants were essentially carried over from the main season, and thus were planted well before the planned seeding for winter production occurred. In addition, the germination problems with Carrots, Cilantro and Snow Peas were assumed to be due to the high soil temperatures at the time that they were sown, although since the Cilantro seeds never germinated at all it is possible that bad seed was responsible. Once the soil temperature cooled Carrot and Snow Pea seeds did germinate but not with sufficient time for the plants to adequately develop with optimal day length prior to the decrease in day length hours of fall. Thus they never reached full maturity prior to the end of December.

While Coleman (2009) may have great success with the planting dates for these crops and varieties in Maine, the uniquely high late-summer temperatures of the Foothills in Colorado appear to require a different strategy. While the crops with short maturation times appear to do fine for early August sowing, the crops with longer maturation times may produce better winter yields if longer maturing varieties are sown prior to the hottest part of the summer. For example, it might be better to sow a very long growing variety of Carrot, Leek or Scallion prior to the onset of high soil temperatures and then treat the crops more as storage crops held over from the main season in situ, harvesting as needed. The same strategy could be used for cut-and-come again greens such as Chard, where the crop is held over in the tunnel from the main season. This strategy may not work for Snow Peas, Cilantro and greens like Spinach and Bok Choy though, since the plants may not thrive or even survive the high temperatures of late summer without bolting. Different varieties of Spinach and Bok Choy with shorter maturation times may work better for late summer sowing.

Second, planting methods seem to be another important determinate of success. No problems were observed with the direct sowing of Arugula, Mustard, Lettuce, Radish and Turnips. Density after germination was very good. But the direct seeding of other crops was similar to our experiences in late, main season sowing, i.e. uneven germination resulting in unsatisfactory density. Our assumption is that the difficulty with keeping seed beds adequately and evenly watered during late summer was responsible for the lowered density of the Bok Choy, Spinach and Kale crops. The alternative of starting seeds in flats remedied this issue in the case of Kale. Doing so did not offset the impairment Spinach, as well as the Pearl Onions, Scallions and Chard, suffered from being transplanted out. Bok Choy and Lettuce that were started in flats did not appear to be impeded.

Better monitoring would also have benefited the Beets and Lettuce crops. While Beets germinated very well, set-backs due to pests might have been avoided by an earlier application of Diatomaceous Earth and a more generous application of Terrad 3. The intercropping of Lettuce and Radish may have been more successful had the Radishes been heavily thinned earlier.

We expected that success in winter production would be achieved if harvest totals met or exceed expected annual yields projected by the FFGC. At the completion of the production and analysis phase of the trial it was observed that only four crops, Arugula, Mustard, Radishes and Turnips met or exceed the yields predicted. We expect that in future seasons, the resolution of issues with planting dates and planting methods will resolve productivity problems so that yield projections may be better achieved. If so, this may also inform yield prediction issues of the FFGC. If it can be shown that predictions for greens and root crops are more likely to be met during winter production than during main season production, the observed difficulty of meeting predicted yields of these crops in the last 3 years at HeartEye Village may be explained by environmental conditions.

Finally, crops carried over from the main season and storage crops held over provided a good amount of buffer and increased the value of the CSA box. Regardless, once the production phase of the trial was concluded, the production issues described above resulted in the value of the winter CSA box being $75 less than anticipated. But the main season CSA box value was significantly higher and thus CSA member participating in both the main and winter season production still received more produce than the amount they paid for their share. Lower than expected retail sales were not due to lack of consumer demand but to lower than expected yields resulting from production issues.

The second goal of the project was to assess how winter production can be conducted in order to minimally impact the yields obtained using bio-intensive methods during the spring and summer months. Rather than seeing the annual growing cycle as two separate seasons, a main season and a winter season, it was more practical to envision it as one long season, extended at both the beginning and the end by production inside the tunnel. Given the limitations of the FFGC, which was not designed for winter production planning, four plans were necessary to coordinate production. These plans accounted for differences between hot and cold weather crops with regard to sowing and final harvest dates as well as variation in marketing avenues, i.e. a CSA program and retail sales. The four plans consisted of one for hot weather crops grown for CSA and retail sales inside the tunnel, one for cold weather crops grown for CSA inside the tunnel, one for cold weather crops grown for retail sales in the tunnel and finally, one for production outside the tunnel of hot and cold weather crops grown for retail sales and a few ranging, hot weather crops grown for the CSA.

As was discovered during the winter production phase of this study, for tunnel cultivation of many cold weather crops in the Foothills, successions planted in the later part of the season must be seeded prior to the end of September. Other crops must be planted prior to the onset of high summer temperatures. In the FFGC plans used for coordinating production, where cold weather crops are cultivated in the tunnel for winter production, there are more successions planned in the later part of the season than would be possible to plant prior to the end of September or prior to the onset of high temperatures. Due to limitations of the FFGC it is necessary to “force” the planning of winter production of these crops. A simple “manual” adjustment would be necessary. Specifically, instead of following the FFGC generated Planting Dates in the later part of the season and Row Feet/wk information, combining successions into fewer but larger ones, would ensure that all are planted prior to the end of September or before the onset of high temperatures. The resulting produce does not need to be harvested per the succession interval planned (weekly vs. biweekly), but rather can be harvested upon maturation at any time.

Hot weather crop planting and harvest information generated by the FFGC also requires adjustment for tunnel production. The FFGC plan accounts for a specific period of production possible for hot weather crops before they are, on average, expected to be spent. When planning to over-winter some of these crops for as long as possible in the tunnel, the final harvest dates generated by the FFGC are often far less than needed when using season extension techniques such as a tunnel. This is especially true when these crops are planted far earlier than the Frost Date for the Foothills allows. It is assumed that some of these plants will continue past the period of time accounted for by the FFGC for how long crops will produce before they are spent. But, to ensure that these crops do produce beyond what is projected by the FFGC, planting them in 2 or more successions may be necessary.

Success in assessing the coordination of main season with winter production was originally anticipated if the coordination could be distilled into a protocol that could be replicated on other micro-farms. Although effective, using the FFGC to plan for season extension and several types of markets is a complex endeavor. While the description of the four FFGC plans required for tunnel production provides such a protocol so to speak, I believe that most would find using it to be too complex to be very practical. But, the results of this study do provide invaluable information for making changes to the FFGC so that it could more easily manage planning complexity as well as account for production and marketing complexities and variation.

The third goal of the project was to assess how much space is necessary to dedicate to winter production to make the entire farming operation sustainable. Success was anticipated if results of the analysis indicated a ratio of fall/winter to spring/summer cultivatable space that would generate sufficient yields to allow micro-farm operations to be sustainable. It was originally thought that the total amount of cultivatable space used at HeartEye Village, 1/10 of an acre, would be sufficient along with some amount of season extension via tunnel production to make the operation financially sustainable. This is not the case though, since by simulating operations using the FFGC and the Financial Projections tools, a minimum of ¼ acre of total cultivatable space was found to be necessary with half of the cultivatable space in tunnel production for season extension. In addition, it was also found that methods to increase yields without increasing cultivatable space, avoiding a commensurate increase in annual labor for plot preparation, were necessary to achieve financial sustainability. Although untested to the degree used in the simulation of a financially sustainable operation described here, intercropping was promoted as a possible solution, at least in theory. Actual ground testing of the technique of intensive intercropping clearly needs to be conducted.

5. OUTREACH

Outreach Venues

The small research trial outlined here is part of a larger pilot study of urban, micro-farming using bio-intensive methods. HeartEye Village CSA is a pilot study micro-farm for Landshare Colorado's Grow Your Own CSA Co-op. The Co-op utilizes a multi-pronged approach to provide prospective urban farmers with assistance. This pilot study of a peri-urban, quarter-acre, micro-farm CSA provides a testing ground (4368 sq ft of cultivatable space) for co-op promoted methods. In addition, the HeartEye Village CSA website provides real-time information on its progress and evolution towards sustainability. This report will be disseminated via the Landshare Colorado website as well as the parent organization website of Colorado Local Sustainability.