[1]The Role of Response Farming Rainfall Forecasts in improving the performance of Agronomic Adaptation Strategies

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Abstract

Farming by resource-poor and inadequately informed farmers with fixed best-bet strategies under seasonal variability and changing climate in the semi-arid Central Rift Valley of Ethiopia has often proven to be of very low flexibility. While, struggling to survive in the face of high risks, farmers in semi arid-arid areas need flexible seasonal adaptation strategies. The "Response Farming" (RF) methodology, a system that derives forecast of seasonal rainfall from very early rain occurrences, and makes choices of crops and practices to conform to the forecasts was evaluated. The potential of RF in improving traditional adaptation measures employed to current rainfall variability and to observed and projected climate change was investigated. RF turned out superior to both research and farmers' production strategies. Our evaluation of climate variability and change interventions (RF) show that adaptation strategies, based on RF modeling using long-term weather records, to be useful keys for improving traditional adaptation strategies and to make farming ecologically sustainable and economically feasible as climate change unfolds.

Key Words: **Poor-resource and inadequately informed farmers, Response Farming, Evaluation, Climate Variability, Climate Change, Adaptation.**

INTRODUCTION

Climate driven agriculture in Ethiopia is the economic mainstay accounting for over 40% of GDP and 90% of national foreign exchange earnings (USDS 2007). The sector being sensitive to climatic variations, experiences frequent droughts resulting in massive food shortages (Reddyand Kidane, 1993). The Initial National Communication of Ethiopia shows a decreasing trend in annual rainfall over Northern and increasing trends over Central parts of the country (UNFCCC 2001). By the year 2030, Global Circulation Model projections show, an increase in temperature by $1^{o}C$ and a decrease in rainfall of up to 2%. According to these projections, climate change is the cause of high current climate variability and will increase the frequency of extreme events making agricultural sector vulnerable culminating in poor harvests and/or complete crop failure. The net result will thus be shortages of food, pasture and animal feeds. Vincent (2004) reported that Ethiopia ranks as the seventh most vulnerable country in Africa to impacts of climate change. Grey and Saddoff (2005) show strong links between Ethiopian economy and climate performance. Rainfall variability currently costs the country over a-third of its growth potential, and, is likely to reduce this potential by 38%, and to increase poverty by

25% over a 12-year period (World Bank 2005, Saddoff 2006). Overall, crop and livestock production are predicted to further dwindle, lagging very much behind population growth, and increase food insecurity at household and national level thus, perpetuating grinding poverty. The sustainability of agricultural production driven by climatic resources in agrarian Ethiopia is at risk of being compromised.

Fortunately recent research hold promise to reduce some adverse effects by formulating suitable adaptation strategies that combines indigenous knowledge, weather information, and modern risk management models, methods, approaches, practices and location specific seasonal climate outlooks. One such climate risk management research has borne a methodology termed Response Farming (RF) (Stewart 1995?). RF is defined as a flexible system of farming in which key decisions affecting crop water utilization and crop yield are modified each season in response to pre-season and early season predictions of season rainfall parameters. RF utilizes localized daily rainfall records to evolve forecast criteria for rainfall in the pending growing season in time to influence decisions that set yield ceilings as well as a set of alternative recommendations for all forecast contingencies. The methodology identifies and quantifies rainfall related risks (Stewart 1995), and guides strategies for addressing them at farm level. The approach couples a seasonal rainfall forecast with appropriate agronomic response tactics concerning crop and cultivar selection, fertilizer application, row/plant spacing and other crop establishment practices. In RF, the time of season onset is the predictor of seasonal rainfall behavior, with prediction criteria and recommendations for procedures being drawn from analyses of historical rainfall. RF prediction is made at onset of rainy season, and at thinning. The initial forecast facilitates first choice of crop types/cultivar maturities to emphasize, initial seed rate and fertilizer and amounts, and conservation tillage modes to adopt. Initial decisions are kept open to facilitate revision of earlier decisions at thinning based on relationships between rainfall received early in the season and eventual total seasonal rainfall. The forecast guides the farmer either in adjusting fertilizer use upward through top dressing (high rainfall), or in thinning plant population (low rainfall) (Stewart and Hash, 1982; McCown et al 1991).

Habtamu (2004), McCown et al (1991), Wafula (1989), and Stewart (1988,) demonstrate the use of RF. They used RF approaches to clarify the relative risks facing alternative cropping strategies developed whether in standard research, traditional farm practice, or those developed through RF analytical models, and pinpoint actions to be taken, concerning the above and several other important decisions farmers must make at the start of each new season. In Kenya, the methodology nearly doubled on-farm bean yields and more than doubled those of maize, while cutting failed maize rate from one season in two (50%) to one in nine (11%) (Stewart 1986; Stewart and Kashasha, 1984). In the good seasons, inter-cropping was reported to be advantageous (Stewart and Faught, 1984). Sivakumar (1988, 1990) adopted duration relations to onset and developed detailed relay inter-cropping of cowpea and sorghum recommendations for Sahelian zones of West Africa.

Many traditional farmers have long used the RF approach to reduce the level of risk they face and increase the returns to their efforts. For example, farmers in semi-arid areas of Ethiopia base their management decisions according to observed season date of onset of rains. They perceive seasons with early onset of rains to be of longer duration, with higher water amounts to grow longer duration crops and cultivars. In late rains onset seasons, they anticipate shorter season limited by water supplies and switch to short term crops. Over years of trial-and-error, they have identified strategies suited to different sets of date of onset, soils and varying moisture regimes (ICRA, 1999; 1997, 1996, Fujisaka et al., 1996). In spite of these traditional perceptions and decision and their favoring of seasonally flexible production technologies, systems improvement research has largely ignored the resource-poor and poor-access to information dryland farmers' own native technical intelligence and traditional practices which have produced important practical developments in weather based crop management. Farmers in question, in their tradition of flexibility view fixed "best bet" cropping system prescriptions, blanket fertility recommendations and fixed soil water conservation procedures (Lemma et al., 1995, Berhane et al., 1993; Reddy and Kidane, 1993, Teshale et al., 1996) as weather insensitive and limited in their use. Consequently, crop productivity gains and overall success in food self sufficiency have been disappointing (Habtamu et al., 1996). Essentially, such understanding and employment of the concept by farmers being already a reality (Stewart 1988, Fujisaka et al 1996, ICRA 1996, 1997, and 1999), there is potential for such systems based on RF to be readily and instantly adopted by farmers both in principle and practice. Overall, the above directly points to the need to build on farmers own traditions than look totally different as is the custom in order to enhance their adaptive capacity through a well-defined action orientated process and validation and use of robust decision support tools for improved strategic and tactical decision making. In this paper, we share field evaluation results of RF methodology in which we evaluated its potential in improving traditional and research based fixed best bets, and prospects for adapting both strategies to current climate variability and explore better strategies that are to be called upon to adapt to observed and projected climate change.

GENERAL METHODOLOGY OF THE STUDY

On-farm trials were carried out in the Central Rift Valley of Ethiopia in the vicinities of Melkassa Agricultural Research Center (MARC) (Adulala, Welenchiti), and Adami Tulu Agricultural Research Center (ATARC) (Adamitulu and Bulbula) during the 2005-2007 seasons, and extended to Meki and Miesso during 2007 cropping season (Table 1).

Table 1 Exact Geographical Description of Measurement Stations, Study Sites as determined by GPS unit and Records Analyzed

Location	Latitude	Longitude	Altitude, m.a.s.l	Period	No of Years of Record Analyzed
MARC Weather station	08^{o}.14'	039^{o}.34'	1578	1977-2000	24
Welenchiti-Marabe Marmarssa	08^{o}36'	039^{o}21'	1488	Represented by MARC	24
ATARC and its vicinities-(Shisho Tebo, Bulbula)	07^{o}50'	038^{o}40'	1710	Represented by ATARC	19
Meki	09^{o}14'	40^{o}.46'	1400	1973-2005	33
Miesso	08^{o} 9'	38^{o}.49'	1400	1967-2005	39

Climatic Characteristics

The study areas are characterized by erratic, low, and unreliable seasonal rainfall exceeded by monthly potential evapo-transpiration even during the rainy season (Habtamu 2004). Occasional strong winds and high evapo-transpiration triggered by high temperatures that exceed 25^0C during the rainy season exacerbate soil moisture stress. Figures 1a-1e depicts a weak mono-modal pattern of rainfall for the study areas. Agriculturally meaningful rains commence in February or March. The inter-annual variability in all areas is exceeded by intra-seasonal variability for all locales. Rainfall amounts at all locales have very high coefficients of variation and hence crop moisture deficit is to be expected in any given time causing frequent crop failure.

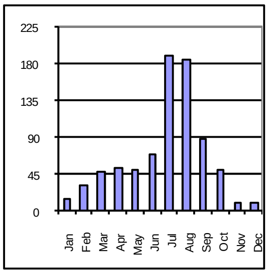

Figure 1a: - 24-Years Mean Monthly Rainfall (mm) at MARC, Data: 1977-2000.

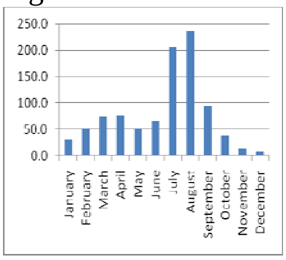

Figure 1b: - 42-Years Mean Monthly Rainfall (mm) at Welenchiti, Data: 1964-2005.

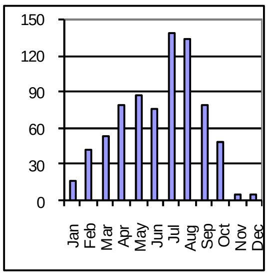

Figure 1c: -19-Years Mean Monthly Rainfall (mm) at ATARC, Data: 1982-2000.

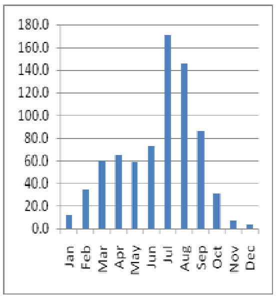

Figure 1d -39-Years Mean Monthly Rainfall (mm) at Meki, Data: 1973-2005.
39 years, mean annual total=748mm.

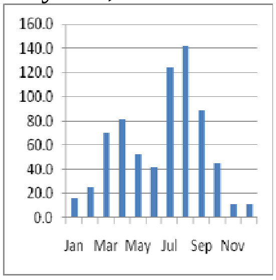

Figure 1e: -33-Years Mean Monthly Rainfall (mm) at Miesso, Data: 1973-2005, 33 years, mean annual total=765 mm.

A single fixed agronomic maize production package is recommended for use by farmers in any given season across the Central Rift Valley regardless of seasons' rainfall potential. Farmers produce maize, teff (*Eragrostis tef*), wheat and haricot bean both for food and cash. Maize is the staple food crop and greatly suffers from moisture stress in different growth periods (Ransom et al., 1997). In order to alleviate effects of soil moisture deficits and consequent crop failure, farmers employ various forms of intervention inherent in RF concept. They grow a range of maize cultivars with varying maturation periods in response to different levels of expected rainfall. Fujisaka, *et al.* (1996), describe three maturity groups of maize grown in the area, all of which are harvested in late November, with longer-term cultivars favored by farmers because, in years with better rainfall, they produce higher yields than the fast maturing varieties. Average yields are low, 1.2 t/ha (0.8 t/ha for short-term maize, 1.0 t/ha for medium, and 1.6 t/ha for long term cultivars) due to low and erratic rainfall and equally low soil fertility. In maize production, farmers apply usually about 50 kg/ha DAP (di-ammonium phosphate), plus some 50 kg/ha urea. This combination provides about 32 kg/ha N, which, considering also natural N regeneration each season, enables average yields around 2.0 t/ha. They sow long duration maize cultivars in mid-April, medium in mid-May, and short term in June. In production of long/medium term maize cultivars, a widely used procedure is to prepare fields with early (Feb-Apr) rains, and sow in April or May. If plant stands are poor or seedlings die due to poor rains, farmers re-plow and re-sow short duration Katumani maize (or sow other short term crops).

Exploring Strategies for Adaptation to Current Season Rainfall Variability

Strategy I: Farmers' Strategies

These are strategies set by farmers based on their own perceptions of seasonal rainfall prospects. They sow a range of maize cultivars suited to different season types and pursue a range of soil, crop and fertility management practices. If a season is perceived as early onset of rains, they expect it to offer longer duration of rain with higher water supplies. Hence, they plant long duration traditional or hybrid maize cultivars in April and medium maturity maize in May. If the season is perceived late, they sow low yielding early maturing maize during late June to early July. Farmers at each locale perceived all three seasons as early, and all their plots were planted with traditional long duration maize cultivars (*sheye*), or hybrid maize (BH-540 Pioneer 532) during late April or medium maturity traditional cultivars (*limat*) during May. Some farmers also planted *Melkassa* II. We observed considerable variation on cultivar choices, but planting dates were similar to those adopted in RF plots. Sowing was mostly by broadcasting at higher seed rates. Most farmers employed their traditional practices on their plots. At some sites, farmers used fertilizer on their own plots, but most of them avoided use of fertilizer at sowing, and used UREA at thinning time, among those who opted to grow hybrids.

Strategy II: Response Farming Forecast Modernized Traditional Strategies

This strategy is farmers' traditional practices modernized by RF forecasts. These were co-managed with farmers, with most decisions left to farmers. Farmers at study sites were provided with RF forecasts before the season begun. We observed considerable variation among farmers at all locales with respect to their choices, and decisions in terms of crop/cultivar selection, timing of planting, seed rates, planting methods, as well as fertilizer type, timing and amounts. Most farmers chose to plant *Melkassa II* at higher seed rates, with fertilizer. When planting in their traditional plots, other farmers either planted their own traditional cultivars or *Melkassa II* or *Pioneer* hybrid maize seed at higher seed rates.

Strategy III: RF strategy

This strategy was developed based on RF percepts. The main aim in RF is to exploit high rainfall seasons potentials, and minimize risk of failure in poor seasons by forecasting the potential of each pending season using rules based on the date of onset and early season cumulative rainfall. We adopted RF concepts to produce/ create fixed recommended strategies and develop RF strategy in a way to enable tactical responses-to adjust crop stand and N level, to match designed practice with seasonal potential. In seasons' forecast of having high rainfall, higher plant populations and side-dressing of additional N are recommended. If seasons forecast show low rainfall, recommendations are, to thin plant stands to reduce demand for soil/water resources to avoid augmenting the initial N fertilizer.

Methodological Details for Detection of Onset Windows

Detailed study of pre-season rainfall events, evaporation rates and soil water holding capacities were first carried out to determine the criteria that should be accepted as the date of onset of rainy seasons. Risk-wise acceptable season onset for MARC was 25 mm of soil water build-up in the 30 cm soil profile. Based on study of 24 years of daily rainfall, we determined two season types differing in their onset date and rain behavior. Of the 24, 15 years realized "early" category with onset from April 1 to June 14, and 9 years realized "late" category with onset between June 15 and July 16. The two season type groupings (detailed methodology not presented here are identified based on study of onset relations to duration and total season water) vary considerably in their seasonal rainfall behavior (Habtamu, et al, 2007). At ATARC, onset criterion was 30 mm soil water during April 1 to July 16. Of the 19 years studied, nine were classified as early with onset from April 1 to 13, and 10 as late (from April 14 to July 16). The differences in time of onset indicate separate crop establishment packages are required to adapt to the two season rainfall behavior patterns. The window for early onset at MARC exceeds that of ATARC. Portable rain gauges were used to record first rain dates at all locations over the three year period. Table 3 show the actual dates and amounts measured on those dates. Considering evaporative rates of the study locations, rainfall above 5 mm was deemed sufficient to term “first rain date” contributing to future build-up of soil water for the onset.

Table 2: Observed First Rain Dates and Recorded Rainfall Amounts on those Dates at MARC and ATARC Vicinities during 2005-2007.

Year	First Rain date		Rainfall Amount, mm	
	MARC	ATARC	MARC	ATARC
2005	25-January (Julian 25)	14-January (Julian 14)	16	11
2006	12-March (Julian 72)	20-March (Julian 80)	6	5
2007	29-January (Julian 29)	2-Ma (Julian 93)	6.1	5.5

Using the equations in Tables 3, the estimated average dates of onset, using the first rain date as a predictor for MARC and its vicinity (Welenchiti and Adulala) ranged from March 20 to May 7, with a mean date of April 13, and Table 4 shows that at ATARC and vicinity, it ranged from March 9 to April 21, with an average date of onset being April 1.

Table 3: Predicted and Actual time of Season onset (Julian day) at MARC during 2005-2007 Cropping Seasons

Year	Date of Onset (DOS), Julian Days	SE of Prediction, Julian days	Observed First Rain Date, Julian Day	Earliest (SE -) DOS Julian days	Latest (SE +) DOS, Julian days	Estimated Average for season, Julian days	Actual Date of Onset, Calendar and Julian Day
2005	= 0.5013 X Julian First Rain Date, Days + 90.528	±24	Jan 25 (25)	March 20 (Julian 79)	May 7 (Julian 127)	April 13 (Julian 103)	April 7 (Julian 97)
2006	= 0.5013 X Julian First Rain Date, Days + 90.529	±24	March 13 (Julian 72)	April 13 (Julian 103)	May 31 (Julian 151)	May 7 (Julian 127)	May 7 (Julian 127)
2007	= 0.5013 X Julian First Rain Date, Days + 90.530	±24	Jan 29 (Julian 29)	March 22 (Julian 81)	May 9 (Julian 129)	April 15 (Julian 105)	April 19, (Julian 109)

Following each rain event, actual occurrences of the predicted onset dates were confirmed through regular monitoring of soil moisture level with auger samples at 15, 30, and 45 cm soil depths. Gravimetric analysis of soil samples taken from 14 farmers’ fields over the three years revealed, onset was observed within the predicted window.

Table 4: Predicted and Actual time of Season onset (Julian day) at ATARC during 2005-2007 Cropping Seasons

Year	Date of Onset, Julian	SE of Prediction, Julian days	Observed First Rain Date, Julian Day	Earliest (SE -) DOS	Latest (SE +) DOS Julian days	Estimated Average for season, Julian days	Actual DOS, Calendar and Julian Day
2005	= 0.4127 X First Rain Date, Julian Day + 84.775	±21.4	January 14 (Julian 14)	March 10 (Julian 69)	April 21 (Julian 111)	March 31 (Julian 90)	April 18 (Julian 108)
2006	= 0.4127 X First Rain Date, Julian Day + 84.775	±21.4	March 21 (Julian 80)	April 6 (Julian 96)	May 19 (Julian 139)	April 27 (Julian 117)	April 29 (Julian 119)
2007	= 0.4127 X First Rain Date, Julian Day + 84.775	±21.4	April 3 (Julian 93)	April 12 (Julian 102)	May 21 (Julian 141)	May 3 (Julian 123)	May 7 (Julian 127)

RF Agronomic Response Tactics for Crop/Cultivar Selection

Detailed studies by Stewart (1988), Habtamu et al, (2004) and Sivakumar (1990) show strong correlation between date of onset and season duration. All authors reported, early seasons to be of longer duration than those starting later. Hence, this relationship is useful for cultivar selection. The estimated date of onset was also used to calculate expected duration and total season water supplies. Table 5 show actual season duration (the number of days from the date of onset to the final rain date) for MARC and Table 6 is for ATARC. Again, seasons' total water supply estimates are important to match selected crop cultivar according to its total water needs and daily water requirement. The initial decision concerns the type of crop to consider for planting depending on the predicted season duration. Table 5 for MARC and its vicinities contains the information which allows initial judgement on the type of maturity group to consider. The same table shows that season duration over the three years was feasible to grow maize cultivar of 90 to 140 days maturity period. *Melkassa II* (ZM-521), maturing in 130 days with potential grain yield of 4.5-5.5t/ha was selected. We adopted this on account of possible delay in onset. Duration estimates for ATARC and vicinity in Table 6 also show similar decisions explained above as feasible.

Table 5: Occurrences in Predicted and Actual Season Duration at MARC during 2005-2007 Cropping Seasons

Year	Season Duration, Days	SE of Prediction, Julian days	Estimated Average season date of onset, Julian days	Shortest expected rainfall season duration, days	Longest Rainfall season duration, days	Estimated Average season rainfall DUR, days	Actual Crop Season sowing to maturity
2005	= -0.9327 X Date of Onset, Julian Days + 257.7	±14 days	103	148	176	162	138
2006	= -0.9327 X Date of Onset, Julian Days + 257.7	±14 days	127	126	154	140	147
2007	= -0.9327 X Date of Onset, Julian Days + 257.7	±14 days	105	146	174	160	153

Tables 7 and 8 for data from MARC and ATARC and their vicinities respectively show the regression equations used to estimate TSW and the estimates of season water supplies (sum of soil water at onset and in-season rain - rainfall from the date of onset to the final rain date affecting the crop).

Table 6: Occurrences in Predicted and Actual Season Duration at ATARC during 2005-2007 Cropping Seasons (Data: 1986-2000)

Year	Season Duration, Days	SE of Prediction, days	Estimated Average season date of onset, Julian days	Estimated Average season date of onset, Julian days	Shortest (SE -) expected season duration, days	Longest season duration, days	Estimated Average season DUR, days
2005	= -0.7498 X Date of Onset, Julian Days + 236.82	±16	90	153	185	169	129
2006	= -0.7498 X Date of Onset, Julian Days + 236.82	±16	118	133	165	149	137
2007	= -0.7498 X Date of Onset, Julian Days + 236.82	±16	123	128	160	144	143

One hundred and thirty (130) days maize water requirement estimates, assuming planting in May revealed the total season water estimates shown in the tables 7 and 8 to be sufficient to achieve ETmax. In addition, the average intensities (total season water divided by season duration) indicated a good probability of success with the selected crop cultivar.

Table 7: Occurrences in Predicted Total Season Water Supplies at MARC during 2005-2007 Cropping Seasons

Year	Total Season Water Supplies, mm	SE of Prediction , (±)	Estimated Average season date of onset, Juliann, days	Least (SE -) TSW supplies , mm	Highest (SE +) TSW supplies , mm	Estimated Average TSW supplies, mm
2005	= -1.6016 X Julian Date of Onset + 823.09	127 mm	103	531	785	658
2006	= -1.6016 X Julian Date of Onset + 823.09	127 mm	127	493	747	620
2007	= -1.6016 X Julian Date of Onset + 823.09	127 mm	105	528	782	655

On RF plots, the prediction guided management practices discussed above was employed. The decision was made to sow all farmers fields with *Melkassa II* maize cultivar with sowing dates adjusted to observed soil moisture within the observed onset time period, with care taken to ensure planting time would avoid the two extremes of being either too early or too late. Fertilizer was used at the rate of 100 Kg/DAP at sowing and 50 kg/ha UREA at thinning as recommended by research, and all management practices aimed at realizing normal yield targets.

Table 8: Predicted Total Season Water Supplies at ATARC during 2005-2007 Cropping Seasons

Year	Total Season Water Supplies, mm	SE of Prediction, (±) mm	Estimated Average season date of onset, Juliann, days	Least (SE -) TSW supplies , mm	Highest (SE +) TSW supplies , mm	Estimated Average TSW supplies, mm
2005	-2.8455 X Date of Onset, Julian Days +951.54	125.1	91	569	819	694
2006	-2.8455 X Date of Onset, Julian Days +951.54	125.1	118	491	742	616
2007	-2.8455 X Date of Onset, Julian Days +951.54	125.1	123	476	726	601

Second Stage RF

Since decisions made early in the season are embedded with uncertainty, an opportunity for revision of such decisions is necessary. RF relies on cumulative amounts of early crop season rainfall from onset to top-dressing and thinning time [traditionally at the time of *shilshalo* - an inter plant oxen cultivation to thin plant population and/or loosen the soil surface to enhance water infiltration] to estimate the remaining seasonal water supplies. The rainfall criteria were determined through detailed season-by-season analyses of early season rainfall [rainfall amounts as from the assumed planting date to thinning time, or to the time period (maximum of 10 days) of acceptable delay in thinning (Habtamu 2007, 2004)] and regressing them on actual season totals until sufficient level of correlation is obtained. If the water outlook is good, additional fertilizer is side-dressed; if poor, plant populations are thinned. We monitored actual rainfall from onset to the second stage decision point, 40-45 days into season. Table 9 show essential correlations between total season water and early season rainfall at MARC and ATARC and estimates of total season water remaining using the equation.

Table 9 shows that, at all locations, over the three years, cumulative rainfall amounts over the 40 days following onset were all in the medium to upper range, hence seasons were categorized as good to fair, and decision was made to keep the original plant population, and add additional N fertilizer with optimal management thereafter. Table 10 summarizes RF procedure adopted with rainfall criteria for judging season category and its potential and corresponding RF strategy. The activity sequence in the table shows decisions that should be made based on the date of onset, separately for early and late seasons, and rainfall totals that signal reduction in plant population. The generalized RF strategy activity sequences according to the rainfall criteria is first, to control weeds and loosen soil by cultivation, and then to adjust plant stand by thinning, and then to apply additional N by side-dressing, while at the same time maintain the tied ridges along with soil blockage every 6 m.

Contingency Plan for Delay in Season Onset

We first planned to explore four strategies. This contingency plan (in-season response tactics) was fixed strategy recommended by MARC for all areas across the semi-arid region. The strategy focuses on shorter term cultivars (90 day and an 80-day extra early maize) grown in rows at spacing of 25 X 75 cm using tied-ridges with application of 100 Kg/ha DAP at planting plus 50kg/ha UREA top-dressed irrespective of season potential. But this contingency plan was of little value to farmers as they predicted early onset with long duration and higher water supply and as they observed all the three seasons turning good as each season unfolded.

In summary, the three strategies tested were a) farmers' traditional maize production strategy without RF inputs b) farmers' traditional maize production strategy with RF forecast inputs, and c) RF, maize production strategy developed based on RF methodology.

Table 9: Estimated Season Water Supplies Based on 40 Day Rainfall Totals at MARC and ATARC during 2005-2007 Cropping Seasons

Year	Location	Total Season Water Supplies, mm	SE of Prediction, mm	40 Day Rainfall Totals, mm	Least (SE -), TSW Expected, mm	Highest (SE +) TSW, Expected, mm	Estimated Average Expected TSW, mm
2005	MARC	TSW, mm = 0.613 X 40 Day R + 571.2, for 40-day rain between 16.7	±113	92	514.6	740.6	627.6

		and 238 mm					
	ATAR C	TSW, mm = 1.1477 X 40 Day R + 187.76, for 40-day rain between 181.9 and 508.7 mm	±58	328	506.2	622.2	564.2
2006	MAR C	TSW, mm = 0.613 X 40 Day R + 571.2, for 40-day rain between 16.7 and 238 mm	±113	101	520.1	746.1	633.1
	ATAR C	TSW, mm = 1.1477 X 40 Day R + 187.76, for 40-day rain between 181.9 and 508.7 mm	±58	297	464.6	580.6	522.6
2007	MAR C	TSW, mm = 0.613 X 40 Day R + 571.2, for 40-day rain between 16.7 and 238 mm	±113	156	553.8	779.8	666.8
	ATAR C	TSW, mm = 1.1477 X 40 Day R + 187.76, for 40-day rain between 181.9 and 508.7 mm	±58	227	384.4	500.4	442.4

Table 10: Using Rainfall Criteria to Adjust Seeding and Fertilization Rates and Using the Actual Rainfall Total at Thinning Time 40 days later to Adjust Final Plant Population and Rate of Nitrogen Side-dressed

Period which includes the dates of onset of rains	April 1-June 14			Late		
40 days cumulative (total) rainfall following onset	R_{total} 167+ mm	R_{total} 92-166 mm	R_{total} 91- mm	R_{total} 401+mm	R_{total} 291-400 mm	R_{total} 290-mm
Type of season	A = Good	B = Fair	C = Poor	A = Good	B = Fair	C = Poor
Plant population after	66,666 ha^{-1}	53,333 ha^{-1}	44,444 ha^{-1}	53,333 ha^{-1}	44,444	38,095

thinning					ha^{-1}	
Fertilizer applied at planting time (DAP)	100 Kg ha^{-1}			100 Kg ha^{-1}		
N to apply at side dressing	50 Kg ha^{-1}	35 Kg ha^{-1}	None	50Kg ha^{-1}	35	None

Data Collection, Analysis and Performance Evaluation of RF Methodology

Key agronomic data and information on farmers perceptions of the various strategies explored were collected; the former data were subjected to simple average analysis. Validation of the performance of RF predictors to guide agronomic planning and farm decision making was conducted at 38 on-farm trials over the three years across semi-arid Central Rift Valley locations of Ethiopia, covering a wide area with considerable rainfall variation. Thorough assessments of farmers' perceptions of performance of various strategies were made during the three seasons. Comparisons of performance of the strategies in terms of final yield were accomplished together with participating farmers and development workers.

Results

Table 12 shows that across all 11 study sites average maize yields were raised by about 58% when RF strategy adopted. Absolute failure was observed at two sites adopting farmers traditional strategies, indicating over 72% gain from use of RF strategies. Average maize yield gains were about 38% when RF forecast information was used to shape farmers strategies. RF holds great promise in reducing failure. This indicates average maize yields from farmers strategies could be raised if RF forecasting is used as compared to farmer's conventional management practices.

Similarly, results presented in Table 13 show gain in maize grain yields from the various strategies tested across 12 on-farm sites during 2006 cropping season. The table shows that gain in maize grain yields were least when adopting traditional strategies across all sites, where as response farming strategies realized highest gain in maize grain yield. Overall, average maize yield gains of about 91% were realized when adopting response farming strategy compared to farmers' practice. Likewise, as was the case in the preceding year, response farming forecast information increased farmer yields by about 45%.

Table 12: Summary of Results from on-farm Evaluation of Maize Production Strategies during 2005 cropping season at 11 sites in the semi-arid Central Rift Valley of Ethiopia

	Adulala				**Welenchiti**			**Bulbula**				**Adami Tulu**				Overall mean, Q/ha
Strategy	Site-1	Site-2	Site-3	Mean Yield (Q/ha)	Site-1	Site-2	Mean Yield (Q/ha)	Site-1	Site-2	Site-3	Mean Yield (Q/ha)	Site-1	Site-2	Site-3	Mean Yield (Q/ha)	

FP*	15.7	0.0	45.3	20.3	0.0	19.3	19.3	15.7	9.9	6.8	10.8	10.7	16.6	19.4	15.6	16.5
FP+RF**	30.3	32	55.5	39.3	19.3	23.1	21.2	14.6	9.8	11.9	12.1	14.9	17.9	21.8	18.2	22.7
RF***	37.8	41.5	62.3	47.2	22.1	26.1	24.1	24.7	18.5	15	19.4	16.8	21.9	30	22.9	28.4

*FP=Farmers Practices, **FP+RF=Plots representing response farming modernized local practices, and ***RF=is response farming strategy.

Table 13: Summary of Results from On-farm Evaluation of Maize Production Strategies during 2006 cropping season at 12 sites in the semi-arid Central Rift Valley of Ethiopia

Strategy	Adulala				Welenchiti				Bulbula				Adami Tulu				
	Site 1	Site 2	Site 3	Mean Yield (Q/ha)	Site 1	Site 2	Site 3	Mean Yield (Q/ha)	Site 1	Site 2	Site 3	Mean Yield (Q/ha)	Site 1	Site 2	Site 3	Mean Yield (Q/ha)	Overall Mean Yield (Q/ha)
FP	21.0	15.2	4.5	13.5	40.4	32.7	13.9	29.0	6.3	5.0	13.5	8.3	37.2	13.4	3.4	18.0	17.2
FP+RF	27.9	17.1	5.6	16.9	50.3	42.6	14.6	35.8	18.1	11.7	20.6	16.8	62.6	15.2	12.7	30.1	24.9
RF	31.8	19.4	14.0	21.7	78.8	50.8	40.2	56.6	21.0	18.2	26.5	21.9	59.3	18.6	14.9	31.0	32.8

Results presented in Table 14 below show performance of the three strategies during 2007 cropping season, averaged over the 12 on-farm sites across the semi-arid Central Rift Valley areas of Ethiopia. Maize yields in sites adopting response farming strategies were increased by more than 42% relative to those from traditional strategies, where response farming augmented traditional strategy; yields were raised by about 11% over the traditional practices. The results for three years are summarized in Table 15. The potential of RF to improve traditional practices is clearly demonstrated by these results.

Table 14: Summary of maize yield Results from On-farm Evaluation of Response Farming Rainfall Predictors in 2007 cropping season at 12 sites in the Central Rift Valley of Ethiopia(Q/ha)

Trt	Adulala			Welenchiti					Bulbula		Adami Tulu				
	Site 1	Site 2	Mean Yield (Q/ha)	Site 1	Site 2	Site 3	Site 4	Mean Yield (Q/ha)	Site 1	Mean Yield (Q/ha)	Site 1	Site 2	Site 3	Mean Yield (Q/ha)	Overall Mean Yield (Q/ha)
FP	62.9	35.0	48.9	27.3	19.1	22.4	25.8	23.6	17.04	17.04	22.1	31.8	10.8	21.6	27.8
FP+ RF	59.2	44.1	51.7	30.7	21.1	27.0	39.1	29.5	24.47	24.47	35.2	41.1	35.5	37.3	35.7

RF	69.2	47.5	58.4	33.0	22.4	28.0	45.1	32.1	27.43	27.43	40.5	44.6	35.7	40.3	39.5

Table 15: Summary of maize yield Results from On-farm Evaluation of Maize Production Strategies during 2005-2007 cropping season at 33 sites across the Semi-arid Central rift Valley of Ethiopia(Q/ha) **.**

	Adulala				Welenchiti				Bulbula				Adami Tulu				Overall Mean
Trt	2005	2006	2007	Mean Yield (Q/ha)	2005	2006	2007	Mean Yield (Q/ha)	2005	2006	2007	Mean Yield (Q/ha)	2005	2006	2007	Mean Yield (Q/ha)	
FP	20.3	13.5	48.9	27.6	19.8	29.0	23.6	24.2	10.8	8.3	17.0	12.0	15.6	18.0	21.6	18.4	20.5
FP+RF	39.3	16.9	51.7	35.9	21.2	35.8	29.5	28.8	12.1	16.8	24.5	17.8	18.2	30.1	37.3	28.5	27.8
RF	47.2	21.7	58.4	42.4	24.1	56.6	32.1	37.6	19.4	21.9	27.4	22.9	22.9	31.0	40.3	31.4	33.6

Figure 6 depicts summary of the three season maize yield results from 33 on-farm sites across the four test locatios. Maize yields from RF strategies exceeded those of traditional practices in all seasons in all the locations. RF increased maize yields by more than 63%, whereas use of forecast information raised yield by more than 35% over farmers' traditional practice.

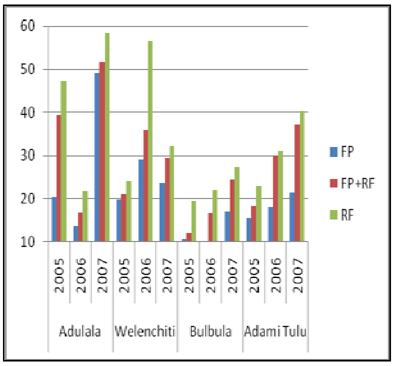

Figure 6: Performance of RF Predictors during 2005-2007 cropping seasons at 35 on-farm sites in four locales in the CRV of Ethiopia.

Figure 7 combines the results depicted in Figure 6, and indicate prospects of RF methodology to blend with and improve traditional farmers' practices and boost overall current low level maize yields.

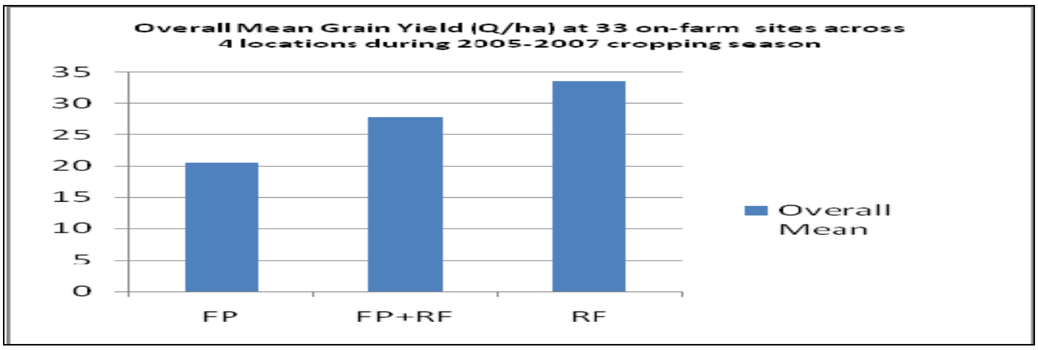

Figure 7: Overall Performance of RF Predictors during 2005-2007 cropping seasons at 33 on-farm sites in four locales in the CRV of Ethiopia.

The on-farm trials were extended to two locations during 2007 cropping seasons. Figure 8 show that the yields from RF plots at the two sites around *Miesso* considerably exceeded those of traditional plots and somewhat exceeded yield from plots where traditional practices were used in conjunction with RF forecast information. RF yields at the two sites at *Meki* were also much superior to maize yields harvested from plots where farmers employed their own practices. The results confirm the potential of RF to improve on traditional practices.

Figure 8: Performance of Rf Predictors during 2007 cropping seasons at *Meki* and *Miesso*

On farm Trial Implementation, Farmers Participation and Farmer Evaluations

Farmers' evaluation of the RF plots was accomplished in a series of meetings. At all sites, the research team met with farmers as a group, and also individually to solicit their cropping decisions according to perceived season category. Research team also discussed the expected types of risks associated with the identified season potential, and their actions and contingency plans for each class. During the initial meetings research team discussed rainfall variability and its influence on cropping, and the rationale for validation of different strategies. RF strategies were clarified to farmers who much appreciated the planned research and fully participated in the process of implementation.

Some of the farmers made their own decisions and planted their own local medium maturity maize. Other farmers wanted to adopt the *Melkassa II* variety, but adjusted the sowing dates according to their local standards. In most cases farmers seriously followed the trials progress throughout the season. Farmers perceived that RF plots were by far superior to their own conventional practices. In cases where farmers' plots recorded zero yields, both participating and non-participating farmers were very much impressed with the performance of the RF farming plots.

Farmers Perceptions of the Feasibility of RF Guided Maize Production Decision Making

Table 16: Farmers perceptions of RF Vs Traditional Practices with and without RF forecasts

Comparison Criteria	**Response Farming Plot**	**Farmers Plot with response Farming forecast**	**Farmers Plot**
Complexity to understand when explained	Similar to their traditional practices, Easy as they adopt similar procedure	Not so confusing, easy to understand	Complexity due to uncertainty associated with great variability in season rainfall onset Simple procedure
Crop management;	Intensive-Labor and capital	Modest fertilizer labour, and weed management	Normal, and decision based on household capacity to take

Input and management level			risk
Timeliness to influence decision	Timely	Did not change	Too early or too late
Chance for revisiting initially set decision	Good indicators to revise chance of success	Plant numbers were reduced at shilshalo due to higher initial plant stand	Plant numbers were reduced at shilshalo due to higher initial plant stand
Grain yield	Very high	Good	Low

Discussion and Conclusions

The validation of the three strategies was the research teams' first experience in Ethiopia to determine the agronomic validity of the RF strategy. The team learned much, and results presented above demonstrates that RF is superior to both farmers' strategies as well as the low yield targeted fixed strategies currently recommended by the research establishment but which were omitted from these trials as all seasons happened to be good. The use of RF forecasts with traditional strategies holds great promise. Since the farmers in the study areas flexibly adjust their management practices according to their perceptions of season date of onset, there is great potential for farmer adoption of RF seasonal forecasts in their decision making. Overall, the approaches examined clearly show good promise of the RF approach for adaptation of cropping decisions to climate change and rainfall variability.

Study results presented in this paper show clear benefits from RF strategies most likely to have come from varietal responses and fertilizer application. At this point, it is not possible to clearly distinguish the differential benefits from N application and higher rainfall amounts because all the three seasons were good from the viewpoint of RF. Further research is needed to quantitatively determine the value of applying the RF modeling approach with a view to separating the value of fertilization from the value of RF forecasts over the long-term historical weather record. In addition, we did not separately assess the performance of RF predictors viz the date of onset and cumulative rainfall since onset; thus there is need to assess the latter. In addition, study did not do any economic valuation. However, studies by Stewart (1988), and extensive validation of the methodology by MCown (1991), Keating et al (1990), and Wafula et al (1990) show great economic benefits from RF strategy as compared to fixed strategies.

To this point, we recommend that the date of onset should be accepted as a predictor of season type, duration, season water supplies and overall potential yield. Keating et al (1990) conclude adjustment of N levels and plant populations to match the season potential as a logical response with good biological basis, despite they reported to assess magnitude of the value to place on the forecast and the potential of use of forecasts to guide farmers practice. In terms of average yields its value over traditional practice was reportedly great indicating a very good potential for improving traditional practice.

Farmers in the study area limit the use of fertilizer due to great seasonal variability in rainfall. The assessments of the RF strategy enables use of fertilizer and promises great potential for adapting seasonal agronomic decision making to current season' rainfall; thereby increasing current low maize yields realized in the area. The need now is to conduct further trials to confirm the benefits of RF in similar agro-ecologies. An additional need is to develop capacity of researchers and development workers in RF analytical methodology, and interpretation of results.

Next thereafter is to learn how best to present RF forecasts and agronomic guidelines to the farming community at the start of each new season, in forms easy to understand and follow in practice. We need to create operational mechanisms in conjunction with grassroots' orientated NGO's and to develop decision support tools which can aid farm advisory services in guiding farmers in their seasonal decision making. Fortunately, farmers in semi-arid areas are very much interested in seasonal rainfall outlook information to guide their decision making. Given the current variability which caps the yield potential of major crops in the area, projections for climate change may make current management strategies very vulnerable. Adaptive mechanisms should be further sought and tested for efficient management of both current variability and projected changes.

Climate information, including historical and real-time, is vital for the optimal management of agriculture and the natural resources on which agriculture depends. When properly integrated with the decision making process, climate information has the potential to moderate the effects of variable climate on food production and ecosystem functions. The need for such integration is more important now than ever due to growing concerns about climate change and its impacts on agriculture (KPC Rao, personal communication). The national meteorological agencies presently offer seasonal outlook information, but are not at all suited to guide farm management decisions. Their projections are crude in nature and wider in coverage making location specific use very difficult. In contrast, seasonal forecasts derived from RF analyses are location specific, and once developed, remain valid throughout the season. Nevertheless, there is a need to source and test the validity, skill and value of different forecast sources as compared to RF strategy in the interest of developing ever more improved adaptive capacity of decision systems both to current variability and projected climate change.

The Way Forward

Extreme climatic events with impacts of varying magnitude are frequent features in Ethiopia. But, recent scientific evidence suggests that the frequency and severity of such events is increasing, making adaptation an extreme necessity. Due to limited adaptive capacity, impacts of these events are beyond control, yet opportunities exist to reduce their adverse effects by formulating effective and efficient adaptation strategies that combine use of indigenous knowledge, risk management practices aimed at better preparedness and mitigation, well-planned responses and strengthened institutions that contribute to enhanced resilience. To this end, we have launched a project on "Managing Risk, Reducing Vulnerability and Enhancing Agricultural Productivity under a Changing Climate", funded by Climate Change Adaptation in Africa (CCAA) Programme of the International Development Research Centre (IDRC) – with overall aim to develop and avail innovative strategies for mitigation of, recovery from, and resilience to climate-induced crises affecting smallholder farmers. Development of such systems requires establishment of a knowledge base that facilitates a well-defined action process by fostering greater understanding of the linkages between climate-related events and vulnerability under different social, political, and economic contexts; development of robust decision making tools for improved strategic and tactical decision making; and formulation of guidelines and mechanisms for multi-stakeholder consultations.

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