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Cooperative Extension Service

Hawaii Rainfall and Forage Production Index Project – Final Performance Report

USDA-NRCS Conservation Initiative Grant
Cooperative Agreement Number 69-9251-7-778

UH Project Number 651563

Submitted by:

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Hawaii Rainfall and Forage Production Index Project
FY 2007 CIG Grant Agreement No. 69-9251-7-778
Final Performance Report, January 15, 2011

Project Background and Objectives:
Sustainable livestock production is dependent on reliable forage resources that will maintain animal health and reproductive fecundity. However, the temporal and spatial variation in forage production in range and pasturelands makes effective grazing management decisions difficult. The temporal and spatial variation in forage production in most range and pasture systems is closely linked to the timing and amount of precipitation. Often livestock producers make grazing management decisions based on past or average forage production levels with little or no certainty that a sufficient amount of precipitation will fall in time to produce what they are counting on. Thus, while during normal precipitation years there is adequate forage to maintain herd productivity; forage resources are wasted when precipitation exceeds long-term averages. On the other hand, overgrazing can result during drought years if herd numbers are not adjusted accordingly.

Precipitation is the most important factor determining the type and amount of productivity of vegetation in range and pasturelands. Many researchers have linked global precipitation patterns to the occurrence of grass, shrub, and forested lands. These studies have also provided regression functions relating Aboveground Net Primary Production (ANPP) with Mean Annual Precipitation (MAP); which are sometimes used as tools to understand the impacts of drought on vegetation production for a given land unit. In Hawaii for example, forage loss assessments are currently derived based on the difference between MAP and annual precipitation for a given year at a given location. This difference correlates to a loss in forage production over the year as a result of drought conditions.

While these globally derived MAP and ANPP functions are useful in developing a general understanding of the relationship between forage production and precipitation, they are of limited use for making management decisions because they are not locally derived. In short, globally derived MAP and ANPP functions cannot account for temporal and spatial precipitation patterns which have as much influence over forage production as total annual precipitation does. For example, summer forage production in most range and pasture systems is dependent on spring precipitation. If spring precipitation is below normal there is a high probability that forage production for the summer grazing period will be less than average. This relationship has been used to forecast forage shortages in several regions of the continental United States in order to prevent severe livestock losses. Thus, development of MAP and ANPP functions that account for temporal and spatial patterns in precipitation inherent to a given local greatly improves the management decision process.

While regional MAP and ANPP functions have been developed for rangelands in the continental United States none exist for sub-tropical and tropical regions like Hawaii. The value of locally derived MAP and ANPP functions cannot be understated as they would be useful for forecasting forage production and suitable stocking rates, drought planning and mitigation, development of prescribed grazing standards, establish soil erosion mitigation standards, and planning range and pasture improvement projects.

The overall purpose of this project was to quantify the relationship between local precipitation patterns with forage production. These data allowed development of MAP and ANPP functions that will be useful for pro-active management of range and pasture lands in Hawaii. This project sought to unite resource production potentials with conservation planning efforts on range and pasture lands. Resource concerns addressed by this project included improving the vigor of plant communities, improving the health of livestock, and reducing soil erosion on range and pasture lands. The project supports USDA-NRCS goals for soil, water, plant and animal health, in addition to working with grazing lands.

The specific objectives of the project were:

1. Establish a network of low-cost precipitation gauges and forage exclosures within each county in the state of Hawaii;
2. Monitor and collect rainfall and forage production data at each station for a minimum of three years;
3. Develop a Rainfall and Forage Production Index that accurately reflects the influence of seasonal and annual variations in precipitation on range and forage resources across a variety of spatial scales (i.e. pasture, precipitation zone, county, state, etc.);
4. Develop a Decision Support Tool and related publications for dissemination and use by producers, and State and Federal agency personnel (USDA-NRCS, FSA, etc.) to assess the impact of drought on range and forage resources and ranch economics.

1. Summary of Project Accomplishments

The period of performance for this project was from August 13, 2007 through September 30, 2010. The following narrative addresses each project deliverable. Following allocation of funds late in September of 2007 the project PI worked to establish agreements from producers in Kauai, Maui, and Hawaii counties and purchase 15 low cost weather stations from Davis Instruments. The stations were received in December of 2007.

1. Establish a network of low-cost precipitation gauges and forage exclosures within each county in the state of Hawaii.

Kauai County

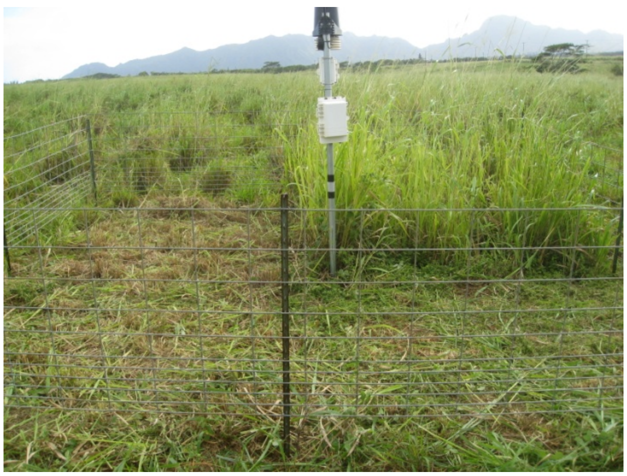
In May of 2008 four of the five weather stations were established on Kauai. The fifth station was installed in August of 2008. These stations were located to represent the different precipitation and vegetation zones that support most of the livestock grazing on the island of Kauai. They include three guineagrass sites, two wet and one dry, and two pangolagrass sites one low elevation, wet, and the other high elevation dry. Each station was installed within an exclosure of approximately 20 ft x 20 ft dimensions.

In November of 2008 KBR4 went down due to an infestation of ants that laid eggs across the circuitry of all the components on the weather station. Various attempts to fix the station were tried and new components were purchased. However it never became fully functional. Data from nearby stations were regressed with the existing data from KBR4 to develop an algorithm to estimate the precipitation (± 10% of the mean) at this station during periods that the station was down. All other stations functioned properly on Kauai.

KOA1
N 21° 57.649' W 159° 25.059'
264 ft. elevation Guineagrass
Wet (> 60" MAP)

KMR2
N 22° 00.377' W 159° 22.445'
362 ft. elevation
Guineagrass
Wet (> 60" MAP)

KPR3
N 22° 12.194' W 159° 26.676'
370 ft. elevation
Pangolagrass
Wet (> 60" MAP)



KBR4
N 22° 03.954' W 159° 20.259'
94 ft. elevation
Guineagrass
Dry (50" MAP)

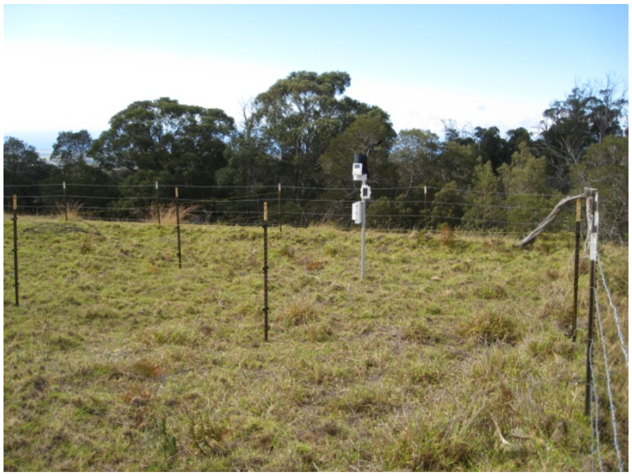
KMWR5
N 22° 00.060' W 159° 36.923'
1,184 ft. elevation
Pangolagrass
Dry (< 30" MAP)

Map of Kauai station locations

Maui County

All five stations for Maui County were established in July of 2008. The station sites to represent the major forage production types on the island of Maui that occur at different elevations and precipitation zones. They include two dry kikuyu grass mix types at high elevation; a wet kikuyugrass type at high elevation; a low elevation wet pangolagrass site; and a low elevation wet guineagrass site. The MHANAR3 station became infested with ants in October of 2009 which shorted out several components on that station as with the KBR2 station on Kauai. Several attempts were made to fix the station and new components were added but it never functioned correctly for the remainder of the study. Data from the nearby NOAA Hana station was used to estimate the missing precipitation data (± 5% of the mean) from MHANAR3. There were no other major malfunctions with the Maui stations.

MHR1
N 20° 47.000’ W 156° 17.204’
4,051 ft elevation
Mix Kikuyugrass
Dry (20-25” MAP)



MHR2
N 20° 47.652' W 156° 18.159'
3,173 ft. elevation
Mix Kikuyugrass
Dry (20-25" MAP)

MHanaR3
N 20° 44.894' W 155° 59.866'
497 ft. elevation
Pangolagrass
Wet (> 60" MAP)

MKR4
N 20° 37.956' W 156° 08.546'
462 ft. elevation
Guineagrass
Wet (>60" MAP)

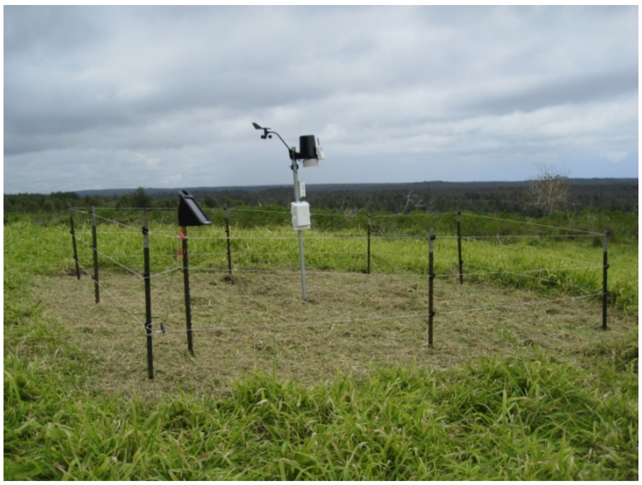
MUR5
N 20° 39.289' W 156° 22.793'
3,070 ft. elevation
Kikuyugrass
Wet (30-35" MAP)

Map of Maui County Stations

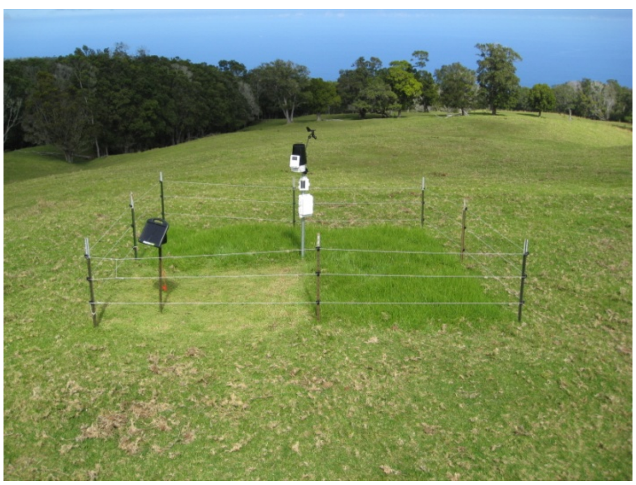
Hawaii County

Establishment of the stations on the Big Island spanned several months due difficulty in site selection, establishing agreements, and other constraints. The first station, BIKPR1 was established in September of 2008, BIPWAI2 and BIHKR3 were established in October of 2008, and BIPHR4 and BIPHR5 were established in January 2009. As with Maui and Kauai, these stations were chosen to represent forage types that support the majority of livestock production on the Big Island across a diversity of precipitation and elevation zones. These stations include a high elevation wet guineagrass site, a high elevation wet Kikyuyu -Pangolagrass site, a high elevation dry kikuyugrass site, a mid-elevation dry buffelgrass site, and a high elevation wet kikuygrass site.

In March of 2010 cattle broke into the exclosure of BIPHR5 and caused damage to the station. A new component was ordered and replaced. Data from a nearby NOAA station was correlated with the existing data from BIPHR5 with 95% accuracy and used to estimate the missing data points. The solar panel on the BIPWAI2 station quit working in November of 2009. However it was not determined that this was problem until months later after several attempts to fix and replace other components. Batteries were constantly replaced while trying to fix the unit in an attempt to keep it functional. The nearby NOAA Honokaa weather station was used to estimate (± 10% of the mean) missing data points for BIPWAI2 station.



BIKPR1
N 19° 19.743' W 155° 24.423'
2,714 ft elevaton
Guineagrass
Wet (60" MAP)



BIPWAI2
N 19° 59.092' W 155° 21.028'
2,941 ft. elevation
Kikuyu-Pangolagrass mix
Wet (> 60" MAP)

BIHKR3
N 19° 29.552' W 155° 50.663'
3,844 ft. elevation
Kikuyu
Dry (< 30" MAP)

BIPHR4
N 20° 08.307' W 155° 49.958'
1,993 ft. elevation
Buffelgrass
Dry (< 20" MAP)

BIPHR5
N 20° 08.073' W 155° 46.788'
3,394 ft. elevation
Kikuyugrass
Wet (>60" MAP)

2. Monitor and collect rainfall and forage production data at each station for a minimum of three years.

The three-year minimum requirement for monitoring forage production and rainfall collection was a logistical oversight. In fact it was not feasible to assume three years of data could be collected given the six months to a year needed to purchase stations, acquirer agreements to host stations from landowners, and to install the stations.

On Maui and Kauai two years of precipitation and forage production data were collected from all stations. Two years of data were collected from BIKPR1 and BIPWAI2. Data from BIPHR4 and BIPHR5 were collected for one and a half years. In the spring of 2010 the ranch hosting BIHKR3 changed hands and access became too restrictive. Thus, the collection from BIHKR3 fell short of two years.

For each station quarterly forage production varied widely within years and across years. Drought in 2010 greatly reduced forage production on all stations. Generally, across the islands 2009 was a wetter year than 2010 though most sites were below the expected MAP.

Forage production on the Big Island was more variable than on Maui or Kauai. The most consistently productive sites were the wet pangolagrass sites on Maui and Kauai (MHanaR3 and KPR3, respectively). The high elevation wet kikuyu site at BIPHR5 had a spike in production that dropped sharply off in late in 2009 as drought began to set in at that location.

Forage production on Kauai generally decreased from 2008 to 2010 as drought set in except at KPR3 which received more precipitation than the other sites throughout the drought. On Maui the high elevation dry kikuyugrass sites (MHR1 and MHR2) had very little variation compared to the other sites. Forage samples for MKR4 from November 2008 through April 2010 as cattle repeatedly broke down the fence to the exclosure. Extreme drought conditions at the MKR4 site resulted in no production from April through July 2010.

Following is a summary of findings by island for the 90 day rainfall totals (inches), Quarterly Forage Production (lbs DM/acre), and Daily Forage Productivity (lbs DM/acre/day). Daily Forage Productivity (DFP) was derived by dividing the Quarterly Forage Production (QFP) values by the number of days between sampling periods, generally 90 days (± 5 days). The DFP is an important component of the rainfall and forage production index discussed in a subsequent section. It will be noted that there was considerable variation in the data within stations and between years. Several more years of data would need to be collected to reduce the variability of the estimates in mean 90 day precipitation and quarterly forage production. This would yield a better Daily Forage Productivity value and a tighter rainfall and forage production index discussed in the next section.

Big Island

Precipitation

Precipitation on the Big Island was highly variable and significantly different between the stations (P< 0.05). Mean 90 day rainfall totals were less for BIHKR3 (3.6 in.), BIKPR1 (7.8 in) and BIPHR4 (5.2 in) than for BIPHR5 (14.4 in) and BIPWA2 (21.1 in).

One-way ANOVA: 90 day Rainfall (in) versus Station

```
Source   DF      SS     MS      F      P
Station   4  1252.1  313.0  10.29  0.000
Error    25   760.4   30.4
Total    29  2012.5

S = 5.515   R-Sq = 62.22%   R-Sq(adj) = 56.17%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean  StDev   -+---------+---------+---------+--------
BIHKR3  6   3.642  1.863   (-----*------)
BIKPR1  7   7.811  4.630         (-----*-----)
BIPHR4  6   5.157  2.540     (-----*------)
BIPHR5  5  14.426  8.461               (-------*------)
BIPWA2  6  21.095  7.691                          (-----*------)
                           -+---------+---------+---------+--------
                          0.0       7.0      14.0      21.0

Pooled StDev = 5.515
```

Quarterly Forage Production (lbs DM/acre)

Quarterly forage production varied across seasons for each station on the Big Island. When compared among stations mean quarterly forage production (lbs. DM/acre) was significantly different (P < 0.05). However average production at BIHKR3 (1080 lbs DM/acre), BIKPR1 (2084 lbs DM/acre), and BIPHR4 (1142 lbs DM/acre) was similar and less than at BIPHR5 (5477 lbs DM/acre) and BIPWA2 (3378 lbs DM/acre).

One-way ANOVA: Quarterly Forage Production (lbs DM/acre) versus Station

```
Source   DF         SS        MS      F      P
Station   4   73304220  18326055  12.79  0.000
Error    25   35807163   1432287
Total    29  109111383

S = 1197   R-Sq = 67.18%   R-Sq(adj) = 61.93%

                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level   N  Mean  StDev  +---------+---------+---------+---------
BIHKR3  6  1080    665  (----*----)
BIKPR1  7  2084   1324        (---*----)
BIPHR4  6  1142    770   (----*----)
BIPHR5  5  5477   1752                        (----*-----)
BIPWA2  6  3378   1253              (----*----)
                        +---------+---------+---------+---------
                        0      2000      4000      6000

Pooled StDev = 1197
```

Daily Forage Productivity (lbs DM/acre/day)

Daily forage productivity (lbs Dm/acre/day) also varied significantly (P< 0.05) between stations on the Big Island. Mean daily forage productivity was greater in BIPHR5 (53.9 lbs DM/acre/day) and BIPAW2 (36.8 lbs DM/acre/day) than in BIHKR3 (10.7 lbs DM/acre/day), BIKPR1 (23.0 lbs DM/acre/day), and BIPHR4 (12.6 lbs DM/acre/day).

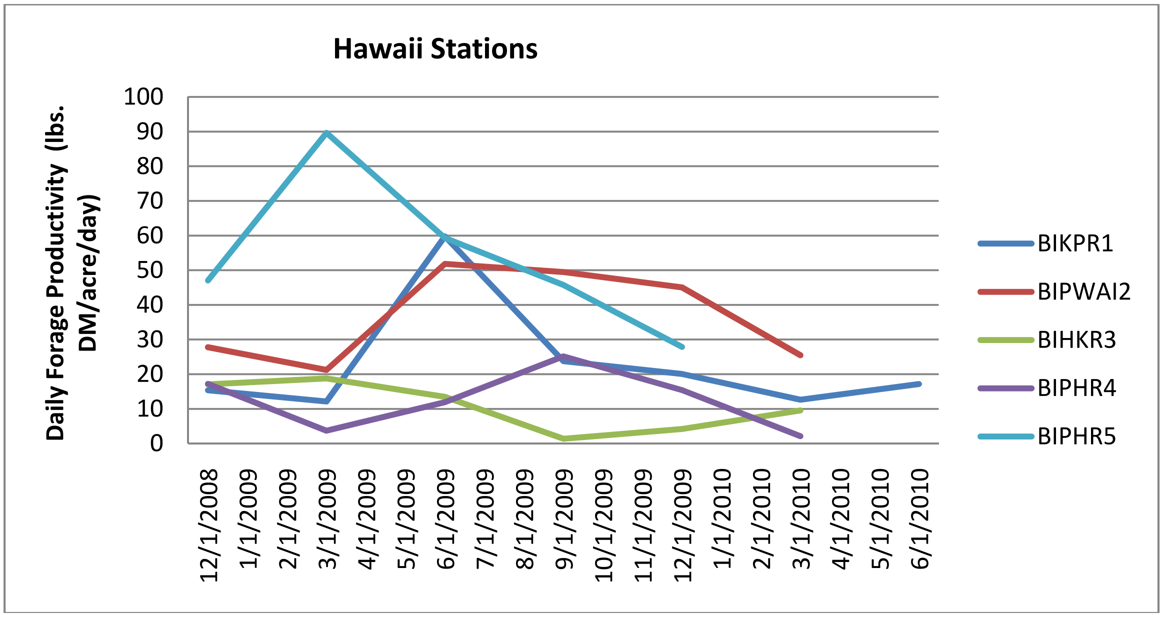
One-way ANOVA: Daily Forage Productivity (lbs DM/acre/day) versus Station

```
Source   DF     SS    MS     F      P
Station   4   7137  1784  8.41  0.000
Error    25   5307   212
Total    29  12444

S = 14.57   R-Sq = 57.35%   R-Sq(adj) = 50.53%

                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level   N   Mean  StDev  -+---------+---------+---------+--------
BIHKR3  6  10.73   7.00  (-----*-----)
BIKPR1  7  22.98  16.73         (----*-----)
BIPHR4  6  12.58   8.68   (-----*-----)
BIPHR5  5  53.92  22.91                         (------*------)
BIPWA2  6  36.81  13.48              (-----*------)
                         -+---------+---------+---------+--------
                          0        20        40        60

Pooled StDev = 14.57
```



Daily Forage Productivity (lbs Dry Matter/acre/day) for the stations on the Big Island.

Maui

Precipitation

Precipitation on Maui was less variable than on the Big Island and Kauai. The mean 90 rainfall totals were not significantly different (P>0.05) among the stations. However, MHR1 and MHR2 received less rainfall (5.6 inches) than MHanaR3 (14.5 in), MKR4 (11.6 in) and MUR5 (11.4 in).

One-way ANOVA: 90 Day Rainfall (in) versus Station

```
Source   DF      SS     MS     F      P
Station   4   500.0  125.0  1.78  0.155
Error    35  2457.6   70.2
Total    39  2957.6

S = 8.380   R-Sq = 16.90%   R-Sq(adj) = 7.41%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level     N    Mean   StDev   -+---------+---------+---------+--------
MHanaR3   8  14.519   7.877                  (---------*---------)
MHR1      8   5.646   4.827   (---------*---------)
MHR2      8   5.653   5.302   (---------*---------)
MKR4      8  11.583   9.193             (---------*---------)
MUR5      8  11.414  12.374             (---------*---------)
                              -+---------+---------+---------+--------
                              0.0       6.0      12.0      18.0

Pooled StDev = 8.380
```

Quarterly Forage Production (lbs DM/acre)

Seasonal variation in quarterly forage production was high for each station on Maui. Mean quarterly forage production among stations was significantly different (P<0.05). The highest average quarterly forage production was at the MHanaR3 station (6273 lbs DM/acre). Stations

MKR4 and MUR5 had the next highest quarterly forage production (4102 and 3770 lbs DM/acre, respectively), while MHR2 had the lowest QFP (1105 lbs DM/acre).

One-way ANOVA: Quarterly Forage Production (lbs DM/acre) versus Station

```
Source   DF         SS        MS     F      P
Station   4  136381375  34095344  6.82  0.000
Error    33  165045534   5001380
Total    37  301426909

S = 2236   R-Sq = 45.25%   R-Sq(adj) = 38.61%


                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level    N  Mean  StDev  --+---------+---------+---------+-------
MHanaR3  8  6273   3713                      (-----*------)
MHR1     8  1658    949    (------*-----)
MHR2     8  1105    335  (-----*------)
MKR4     6  4102   2904            (------*-------)
MUR5     8  3770   1659            (-----*------)
                         --+---------+---------+---------+-------
                           0      2500      5000      7500

Pooled StDev = 2236
```

Daily Forage Productivity (lbs DM/acre/day)

Daily forage productivity varied across seasons for each station. Mean DFP was significantly different ($P<0.05$) among the stations. The average DFP for MHR1 and MHR2 (18.7 and 12.3 lbs DM/acre/day) were similar and considerably lower than the other stations. Stations MKR4 and MUR5 likewise had similar average DFP (44.8 and 41.8 lbs DM/acre/day), while MHanaR3 had the highest (68.2 lbs DM/acre/day).

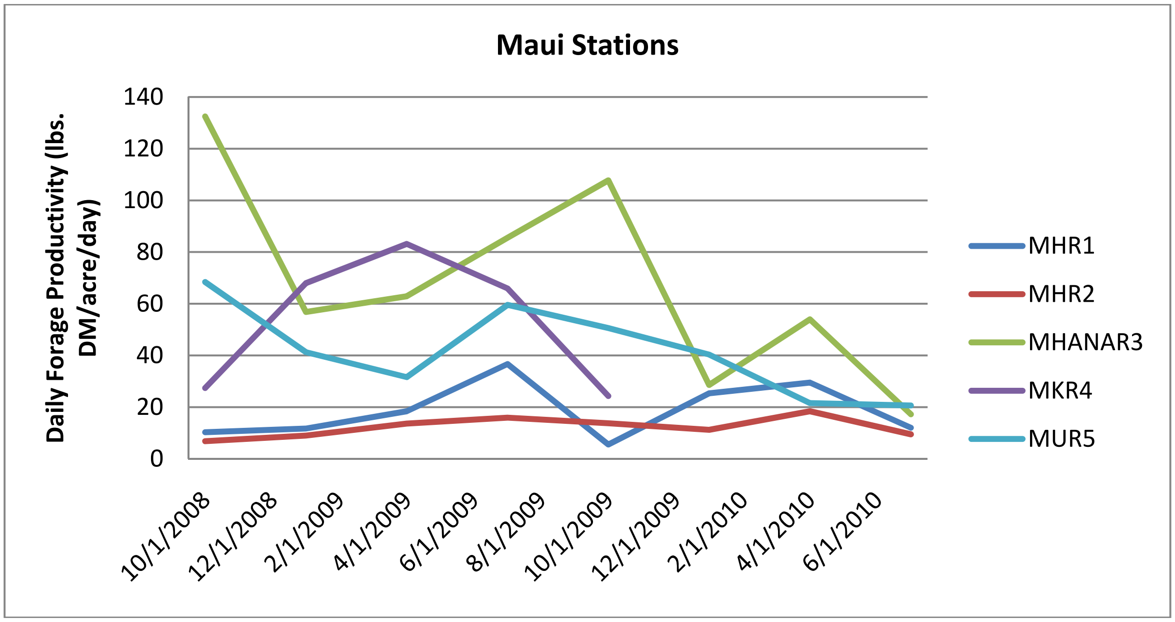
One-way ANOVA: Daily Forage Productivity (lbs DM/acre/day) versus Station

```
Source   DF     SS    MS     F      P
Station   4  15883  3971  7.01  0.000
Error    33  18704   567
Total    37  34587

S = 23.81   R-Sq = 45.92%   R-Sq(adj) = 39.37%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev  --+---------+---------+---------+-------
MHanaR3  8  68.16  38.78                        (------*------)
MHR1     8  18.70  10.84     (-----*------)
MHR2     8  12.28   3.86  (------*------)
MKR4     6  44.80  32.20              (-------*-------)
MUR5     8  41.75  17.18              (------*------)
                          --+---------+---------+---------+-------
                            0        25        50        75

Pooled StDev = 23.81
```



Daily Forage Productivity (lbs Dry Matter/acre/day) for the stations on Maui.

Kauai

Precipitation

Ninety day rainfall totals on Kauai varied by station across seasons. Mean 90 day precipitation however was not significantly different at a probability of 0.05 due mainly to the large variability across the seasons. Stations KBR4 and KMWR5 were dryer (5.3 and 7.4 in) than the other three stations. Mean 90 day precipitation was highest at KOA1 (16.9 in) followed by KPR3 (15.2 in) and then KMR2 (10.2 in).

One-way ANOVA: 90 Day Rainfall (in) versus Station

```
Source   DF      SS     MS     F      P
Station   4   766.7  191.7  2.54  0.058
Error    34  2564.2   75.4
Total    38  3330.9

S = 8.684   R-Sq = 23.02%   R-Sq(adj) = 13.96%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
KBR4    8   5.339   4.041   (--------*--------)
KMR2    8  10.237   8.653          (--------*--------)
KMWR5   7   7.463  10.218     (---------*--------)
KOA1    8  16.871   8.729                   (--------*--------)
KPR3    8  15.225  10.460                 (--------*--------)
                            -+---------+---------+---------+--------
                           0.0       7.0      14.0      21.0

Pooled StDev = 8.684
```

Quarterly Forage Production (lbs DM/acre)

Quarterly forage production varied across seasons for each station on Kauai. Mean quarterly forage production was significantly different among stations (P<0.05). However the average quarterly forage production on KPR3 (5068 lbs DM/acre) was considerably greater than for KBR4 (2290 lbs DM/acre), KMR2 (2895 lbs DM/acre), KMWR5 (2019 lbs DM/acre), and KOA1 (3028 lbs DM/acre) which were all similar.

One-way ANOVA: Quarterly Forage Production (lbs DM/acre) versus Station

```
Source   DF         SS        MS     F      P
Station   4   44798951  11199738  4.85  0.003
Error    34   78578105   2311121
Total    38  123377056

S = 1520   R-Sq = 36.31%   R-Sq(adj) = 28.82%

                       Individual 95% CIs For Mean Based on
                       Pooled StDev
Level  N  Mean  StDev  ----+---------+---------+---------+-----
KBR4   8  2290   1940    (------*-------)
KMR2   8  2895    532        (------*-------)
KMWR5  7  2019   1381  (------*-------)
KOA1   8  3028   1591         (------*------)
KPR3   8  5068   1736                       (------*------)
                       ----+---------+---------+---------+-----
                        1500      3000      4500      6000

Pooled StDev = 1520
```

Daily Forage Productivity (lbs DM/acre/day)

Daily forage productivity varied seasonally for each station. Mean DFP was significantly different between stations (P<0.05). However, average DFP was very similar for KBR4, KMR2, KMWR5, and KOA1 (23.7, 29.7, 20.7, and 28.8 lbs DM/acre/day, respectively). The highest average DFP was at the KPR3 (50.7 lbs DM/acre/day) station.

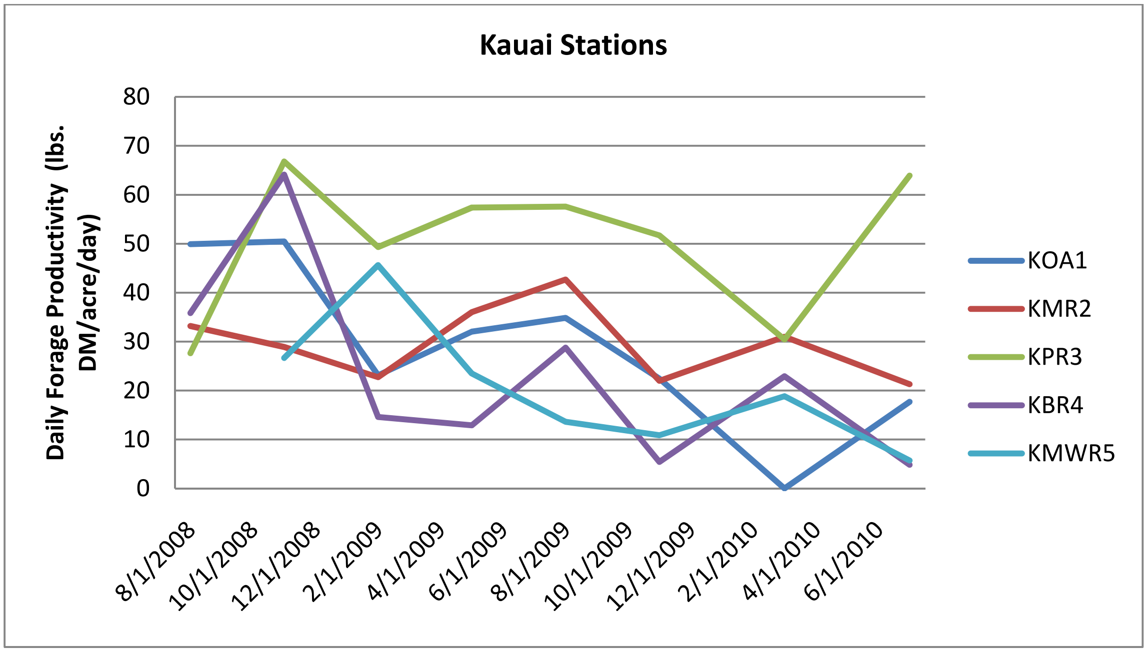
One-way ANOVA: Daily Forage Productivity (lbs DM/acre/day) versus Station

```
Source   DF     SS    MS     F      P
Station   4   4333  1083  4.84  0.003
Error    34   7610   224
Total    38  11943

S = 14.96   R-Sq = 36.28%   R-Sq(adj) = 28.78%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N   Mean  StDev  ----+---------+---------+---------+-----
KBR4   8  23.68  19.63     (------*------)
KMR2   8  29.73   7.58         (------*------)
KMWR5  7  20.70  13.16  (-------*------)
KOA1   8  28.82  16.85        (------*------)
KPR3   8  50.72  14.57                       (------*------)
                        ----+---------+---------+---------+-----
                           15        30        45        60

Pooled StDev = 14.96
```



Daily Forage Productivity (lbs Dry Matter/acre/day) for the stations on Kauai.

All Islands

Precipitation
Mean 90 day precipitation was not significantly different between islands (P>0.05). Kauai had a slightly higher average 90 day precipitation total (11.1 in) than Maui (9.8 in) and Big Island (10.2 in).

One-way ANOVA: Rainfall (in) versus Island

```
Source   DF      SS    MS     F      P
Island    2    37.4  18.7  0.24  0.788
Error   106  8300.9  78.3
Total   108  8338.3

S = 8.849   R-Sq = 0.45%   R-Sq(adj) = 0.00%

                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level    N    Mean  StDev  -----+---------+---------+---------+----
Maui    40   9.763  8.708  (-------------*-------------)
Kauai   39  11.118  9.362         (-------------*-------------)
BI      30  10.206  8.330  (---------------*---------------)
                           -----+---------+---------+---------+----
                              8.0      10.0      12.0      14.0

Pooled StDev = 8.849
```

Quarterly Forage Production (lbs DM/acre)
Mean Quarterly Forage Production between Islands was not significantly different (P> 0.05). Average QFP on Maui was greater (3344 lbs DM/acre) than on Kauai (3087 lbs DM/acre) and Big Island (2519 lbs DM/acre).

One-way ANOVA: Forage Prod (lbs DM/acre) versus Island
```
Source   DF         SS       MS     F      P
Island    2   11684151  5842075  1.14  0.324
Error   104  533915348  5133801
Total   106  545599499

S = 2266   R-Sq = 2.14%   R-Sq(adj) = 0.26%

                        Individual 95% CIs For Mean Based on Pooled StDev
Level   N  Mean  StDev  --+---------+---------+---------+-------
Maui   38  3344   2854                  (-----------*-----------)
Kauai  39  3087   1802             (-----------*-----------)
BI     30  2519   1940  (-------------*-------------)
                        --+---------+---------+---------+-------
                        1800      2400      3000      3600

Pooled StDev = 2266
```

Daily Forage Productivity (lbs DM/acre/day)
Mean Daily Forage Productivity (lbs DM/acre/day) did not vary significantly between islands (P>0.05). Maui had a higher average DFP (36.7 lbs cm/acre/day) than Kauai (31 lbs DM/acre/day) and Big Island (26.4 lbs. DM/acre/day).

One-way ANOVA: Daily Forage Productivity (lbs DM/acre/day) versus Island
```
Source   DF     SS   MS     F      P
Island    2   1834  917  1.62  0.203
Error   104  58974  567
Total   106  60808

S = 23.81   R-Sq = 3.02%   R-Sq(adj) = 1.15%

                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level   N   Mean  StDev  -----+---------+---------+---------+----
Maui   38  36.73  30.57                  (---------*----------)
Kauai  39  30.99  17.73           (----------*----------)
BI     30  26.37  20.71  (------------*-----------)
                         -----+---------+---------+---------+----
                           21.0      28.0      35.0      42.0

Pooled StDev = 23.81
```

3. Develop a Rainfall and Forage Production Index that accurately reflects the influence of seasonal and annual variations in precipitation on range and forage resources across a variety of spatial scales (i.e. pasture, precipitation zone, county, state, etc.).

The primary goal of this project was the development of an index to project forage availability given a certain amount of rainfall; the Rainfall and Forage Production Index. A couple of methods for deriving formulas to estimate forage production from precipitation were investigated.

<u>Method 1.</u>

The first method used linear regression functions based on the 90 day rainfall totals and Quarterly Forage Production values or the Daily Forage Productivity. At the station level the seasonal and annual variation was too large for the sample size (4 quarters x 2 years = 8 sample points) to yield good correlations between precipitation and the production estimates. Several more years of data collection would be necessary to tighten up the relationships at the station level. A tighter relationship was achieved by combining the average 90 day precipitation values and either the QFP or DFP values for each station to derive an index for each island. These regression analyses yielded the following indices:

Big Island

1. **QFP = 693 + 186.0 x 90 day rain total.**

Regression Analysis: QFP versus Avg 90 rain

```
The regression equation is
QFP = 693 + 186.0 Avg 90 rain

S = 1448.78   R-Sq = 53.6%   R-Sq(adj) = 38.2%

Analysis of Variance
Source      DF        SS       MS     F      P
Regression   1   7283298  7283298  3.47  0.159
Error        3   6296921  2098974
Total        4  13580219
```

2. **DFP = 7.13 + 1.944 x 90 day rain total.**

Regression Analysis: DFP versus Avg 90 rain

```
The regression equation is
DFP = 7.13 + 1.944 Avg 90 rain

S = 13.0785   R-Sq = 60.8%   R-Sq(adj) = 47.7%

Analysis of Variance
Source      DF       SS       MS     F      P
Regression   1   795.59  795.586  4.65  0.120
Error        3   513.14  171.048
Total        4  1308.73
```

Kauai

1. **QFP = 1197 + 169.0 x 90 day rain total.**

Regression Analysis: QFP versus Avg 90 rain

```
The regression equation is
QFP = 1197 + 169.0 Avg 90 rain

S = 992.682   R-Sq = 48.5%   R-Sq(adj) = 31.3%

Analysis of Variance
Source      DF       SS       MS     F      P
Regression   1  2782614  2782614  2.82  0.191
Error        3  2956252   985417
Total        4  5738866
```

2. **DFP = 13.83 + 1.533 x 90 day rain total**

Regression Analysis: DFP versus Avg 90 rain

```
The regression equation is
DFP = 13.83 + 1.533 Avg 90 rain

S = 10.4174   R-Sq = 41.3%   R-Sq(adj) = 21.7%

Analysis of Variance
Source      DF       SS       MS     F      P
Regression   1  228.965  228.965  2.11  0.242
Error        3  325.568  108.523
Total        4  554.534
```

Maui

1. **QFP = -1711 + 538.4 x 90 day rain total**

Regression Analysis: QFP versus Avg 90 rain

```
The regression equation is
QFP = - 1711 + 538.4 Avg 90 rain

S = 512.286   R-Sq = 95.8%   R-Sq(adj) = 94.4%


Analysis of Variance
Source      DF        SS        MS      F      P
Regression   1  18117260  18117260  69.03  0.004
Error        3    787310    262437
Total        4  18904570
```

2. **DFP = -17.86 + 5.817 x 90 day rain total.**

Regression Analysis: avg Prodvty versus Avg 90 rain

```
The regression equation is
avg Prodvty = - 17.86 + 5.817 Avg 90 rain

S = 5.40817   R-Sq = 96.0%   R-Sq(adj) = 94.7%

Analysis of Variance
Source      DF       SS       MS      F      P
Regression   1  2114.54  2114.54  72.30  0.003
Error        3    87.74    29.25
Total        4  2202.28
```

All Islands

1. **QFP = 643.1 + 234.1 x 90 day rain total.**

Regression Analysis: QFP versus Avg 90 rain

```
The regression equation is
QFP = 643.1 + 234.1 Avg 90 rain

S = 1233.75   R-Sq = 50.9%   R-Sq(adj) = 47.1%

Analysis of Variance
Source      DF        SS        MS      F      P
Regression   1  20525132  20525132  13.48  0.003
Error       13  19787709   1522131
Total       14  40312842
```

2. **DFP = 7.471 + 2.392 x 90 day rain total**.

Regression Analysis: DFP versus Avg 90 rain

```
The regression equation is
DFP = 7.471 + 2.392 Avg 90 rain

S = 13.2314   R-Sq = 48.5%   R-Sq(adj) = 44.5%

Analysis of Variance
Source      DF       SS       MS      F      P
Regression   1  2141.41  2141.41  12.23  0.004
Error       13  2275.92   175.07
Total       14  4417.33
```

The regression function for both QFP and DFP for the Big Island and Kauai were not significant at the $P < 0.10$ level. However, the R^2 for these functions (BI, R^2 = 53.6% and 60.8%, respectively; Kauai, R^2 = 48.5% and 41.3%, respectively) suggest that there is a potential for a significant relationship given sufficient data to reduce the variability. Comparatively, the relationship between 90 day precipitation and QFP and DFP is much stronger on Maui (R^2 = 95.8% and 96%, respectively) and was significant at the P<0.10 level. When all islands were combined the R^2 for QFP and DFP (50.9% and 48.5%, respectively) showed a moderate relationship between precipitation and forage production. However, the regression function for each were significant at a P<0.10 level. Given this and the fact that between islands there were no significant differences in average QFP and DFP between the islands it would be practical to use the indices to estimate these two variables. Certainly it is much easier and less complicated to have a single index for the state than multiple indices. However, there may be times when it might be desirable to have an estimate that is more locally significant. Additional data collection (several years) would be needed to improve the relationship between rainfall and forage production for each island.

These indices can be used to estimate the amount of forage that was produced for any given 90 day period. It would be useful in determining forage production loss for the NAP forage program administered by the USDA-Farm Service Agency. Below is a summary of the quarterly forage production indices derived from this project.

Summary of Indices to estimate QFP and DFP given 90 day rainfall totals by island and all islands combined along with associated statistics.

Island	Index/Formula	R^2	P
Big Island	QFP = 693 + 186.0 x 90 day rain total	53.6%	0.159
	DFP = 7.13 + 1.944 x 90 day rain total	60.8%	0.120
Kauai	QFP = 1197 + 169.0 x 90 day rain total	48.5%	0.191
	DFP = 13.83 + 1.533 x 90 day rain total	41.3%	0.242
Maui	QFP = -1711 + 538.4 x 90 day rain total	95.8%	0.004
	DFP = -17.86 + 5.817 x 90 day rain total	96.0%	0.003
All Islands	QFP = 643.1 + 234.1 x 90 day rain total	50.9%	0.003
	DFP = 7.471 + 2.392 x 90 day rain total	48.5%	0.004

Method 2.

As second method investigated combined the 90 day rainfall totals (inches) with the Daily Forage Productivity (DFP = lbs DM/acre/day) values for each station yielding a quotient quantifying the daily forage productivity per inch of rain (Daily Forage Productivity Quotient = lbs DM/acre/day/inch of rain). The Daily Forage Productivity Quotient (DFPQ) allows forecasting of the amount of available forage over the next 90 day period. Essentially the DFPQ is a reflection of the water use efficiency of the forages. It should be noted though that several other factors contribute to the variability found the DFPQ for each station soil-moisture relationships and air temperature being the most significant.

One-way analyses of variance were run by island to determine if significant differences existed between stations on each island. Variation across seasons within each station was high resulting in no significant difference (P>0.05) among stations within island.

On the Big Island the highest DFPQ was at BIPHR5 (4.6 lbs. DM/acre/day/inch of rain), followed by BIKPR1 (4.1 lbs. DM/acre/day/inch of rain), and GIHKR3 and BIHPR4 (3.1 and 2.6 lbs. DM/acre/day/inch of rain, respectively). The BIPWA2 station had the lowest DFPQ at 2 lbs DM/acre/day/inch of rain.

One-way ANOVA: DFPQ (Big Island) versus Station

```
Source   DF      SS    MS     F      P
Station   4   26.20  6.55  1.33  0.286
Error    25  122.94  4.92
Total    29  149.14

S = 2.218   R-Sq = 17.57%   R-Sq(adj) = 4.38%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level   N   Mean  StDev  ---------+---------+---------+---------+
BIHKR3  6  3.067  1.836       (--------*---------)
BIKPR1  7  4.094  3.011             (-------*--------)
BIPHR4  6  2.573  1.628     (--------*--------)
BIPHR5  5  4.573  2.874              (---------*---------)
BIPWA2  6  1.992  1.040  (--------*--------)
                         ---------+---------+---------+---------+
                                2.0       4.0       6.0       8.0

Pooled StDev = 2.218
```

Kauai DFPQ values ranged from a high of 9.6 lbs DM/acre/day/inch at KMWR5 to a low of 2.1 lbs DM/acre/day/inch at KOA1. In between were KBR4, KMR2, and KPR3 (5.9, 4.8, and 4.3 lbs DM/acre/day/inch, respectively).

One-way ANOVA: DFPQ (Kauai) versus Station

```
Source   DF      SS    MS     F      P
Station   4   219.8  54.9  1.31  0.287
Error    33  1384.3  41.9
Total    37  1604.1

S = 6.477   R-Sq = 13.70%   R-Sq(adj) = 3.24%

                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level  N   Mean   StDev  -----+---------+---------+---------+----
KBR4   7  5.857   5.119        (---------*---------)
KMR2   8  4.765   3.088      (---------*--------)
KMWR5  7  9.580  13.599               (---------*---------)
KOA1   8  2.145   1.512  (--------*---------)
KPR3   8  4.317   2.229     (---------*--------)
                         -----+---------+---------+---------+----
                            0.0       5.0      10.0      15.0
Pooled StDev = 6.477
```

Variation between stations on Maui was less than on Big Island and Kauai and generally the DFPQ values were greater. The MHR2 station had the highest average DFPQ (8.8 lbs DM/acre/day/inch), followed closely by MHR1 (8 lbs DM/acre/day/inch). Lower average DFPQ values occurred at MHanaR3, MUR5, and MKR4 (5.6, 5.4, and 4.5 lbs DM/acre/day/inch, respectively).

One-way ANOVA: rain Prod versus Station

```
Source   DF      SS    MS     F      P
Station   4    97.0  24.2  0.30  0.878
Error    33  2695.8  81.7
Total    37  2792.7

S = 9.038   R-Sq = 3.47%   R-Sq(adj) = 0.00%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N   Mean   StDev  ------+---------+---------+---------+---
MHanaR3  8  5.646   4.538      (------------*------------)
MHR1     8  7.950   8.266           (------------*-----------)
MHR2     8  8.767  16.638             (------------*------------)
MKR4     6  4.513   4.287  (--------------*-------------)
MUR5     8  5.403   2.501      (------------*------------)
                           ------+---------+---------+---------+---
                               0.0       5.0      10.0      15.0
Pooled StDev = 9.038
```

Because station differences within island were not significant it was possible to combine the average station DFPQ values into a single estimate for each island. One-way analysis of variance on this combined data showed a significant difference (P=0.05) in average DFPQ between islands. Maui had a higher average DFPQ (6.6 lbs DM/acre/day/inch) than Kauai (5.3 lbs DM/acre/day/inch) and Big Island (3.3 lbs DM/acre/day/inch).

One-way ANOVA: DFPQ (All Islands) versus Island

```
Source  DF     SS     MS     F      P
Island   2  29.00  14.50  3.90  0.050
Error   12  44.63   3.72
Total   14  73.63

S = 1.929   R-Sq = 39.38%   R-Sq(adj) = 29.28%

                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N   Mean  StDev  ---+---------+---------+---------+------
Maui   5  6.636  1.601                   (--------*---------)
Kauai  5  5.333  2.731            (---------*--------)
BI     5  3.260  1.065  (--------*---------)
                        ---+---------+---------+---------+------
                         2.0       4.0       6.0       8.0
Pooled StDev = 1.929
```

The DFPQ derived for each island accurately capture the seasonal and spatial variability within each island. Because there were significant differences in the average DFPQ between islands it is recommended that the specific value derived for each island be used.

The DFPQ is a reflection of the water use efficiency of the forages in the pasture. This of course varies between forage species and across sites being influenced by both soil-moisture relationships and air temperature as they affect plant productivity. The DFPQ be used to forecast the amount of forage that will be available over any given interval. This interval is not a specific period (i.e. March to May) but is dynamic and can be updated as rainfall is recorded. The most useful interval would be monthly estimates i.e. as rainfall is totaled for each month an estimate of the available forage for the next month could be estimated. For example 1.5 inches of rain received in a storm on the Big Island would result in production of 4.95 lbs DM/acre/day (3.3 DFPQ x 1.5 inches of rain) over the next 30 days and would yield 148.5 lbs/DM/acre (4.95 lbs DM/acre/day x 30 days). Generally, forage production from any single, significant rainfall event (> 0.5 inches) begins to taper after about 20-30 days as soil water availability decreases. Of course this is dependent on the size of the rainfall event, air temperature, and soil moisture relationships.

Another important use of the DFPQ will be the estimate of critical threshold levels of available forage as drought begins to develop. Because the DFPQ allows the estimate of available forage over the next 90 day interval, producers can anticipate when they will run out of forage for their livestock knowing their stocking rate and the number of days since the last rainfall. For example, a 20 acre Big Island pasture that will be stocked with 5 animal units (AU) received 1.5 inches of rain 15 days ago. The 30 day forage production for the pasture is 4,445 lbs/DM (148.5 lbs DM/acre/day x 30 acres). Proper stocking would allocate half (50%) of the total production to be grazed. Thus the pasture will provide 85.5 AUD (4,445 lbs/DM x 0.5/ 26 lbs DM/AU). This translates to 17 days of grazing for the 5 AUs using the pasture (85.5 AUD / 5 AU). Since the rainfall occurred 15 days ago livestock using the pasture have only two days of forage availability remaining.

Daily Forage Productivity Quotient (lbs DM/acre/day/inch of rain) for each island.

Island	Daily Forage Productivity Quotient
Maui	6.6 lbs DM/acre/day/inch of rain
Kauai	5.2 lbs DM/acre/day/inch of rain
Big Island	3.2 lbs DM/acre/day/inch of rain

4. Develop a Decision Support Tool and related publications for dissemination and use by producers, and State and Federal agency personnel (USDA-NRCS, FSA, etc.) to assess the impact of drought on range and forage resources and ranch economics.

Two decision support tools have been developed utilizing both types of indices described in the previous section. They are reported here and will be incorporated into a CTAHR publication discussing range and pasture management practices during drought.

<u>Decision Support Tool 1.</u>

The first tool can be used to determine the amount of forage produced over a given 90 day period and will facilitate estimating the impact of drought on forage resources and ranch economics. The tool utilizes the Mean Annual Precipitation values that can be obtained from existing NOAA weather stations and the appropriate QFP index for a given island.

Since droughts are dynamic and develop at any given time within the year it is difficult to estimate the impact of a drought on forage resource looking at annual production. In recent years for example, Hawaii has suffered from drought that have been abbreviated by large rainfall events near the end of the year (December) that have no value in determining forage production for the previous 11 months. It would be more effective if each quarter can be evaluated individually as this would make the determination of forage loss more accurate across the year. Below is an example of the use of this decision support tool.

In 2009 the Kamuela area received the following rainfall (the Kamuela station is a NOAA-National Weather Service Station located at the Mealani Experiment Station in Kamuela Hawaii). Mean Annual Precipitation at the Kamuela station site is 60 inches.

In this example monthly MAP and 2009 precipitation amounts were summed by quarter and Quarterly Forage Production (lbs DM/acre) was calculated using the QFP formula for the Big Island (QFP = 693 + 186 x 90 day rain). The percent departure of 2009 precipitation from the MAP was calculated (1 – 2009 precipitation/MAP x 100) as was the percent departure in estimated forage production (1 – 2009 QFP/MAP forage production estimate). The estimates of QFP closely match what was measured over the duration of the study for the high elevation kikuyu grass sites on the Big Island. An estimate of total annual production can be derived by summing the QFP values. In the below example the sum of the QFP values derived from MAP yields a production potential of 13,932 lbs DM/acre. This aligns well with the 12 month production obtained from BIPWA2 (12,933 lbs DM/acre) in 2009. BIPWA2 is a kikuyugrass site with similar rainfall patterns as the Kamuela station.

Station:	Kamuela			
Month	**MAP**	**2009**	**Diff**	**%MAP**
January	6.6	2.86	3.74	0.433333
February	6	5.32	0.68	0.886667
March	7.9	3.88	4.02	0.491139
April	6.9	2.48	4.42	0.35942
May	4	0.82	3.18	0.205
June	2.2	1.45	0.75	0.659091
July	3.7	3.41	0.29	0.921622
August	4.1	4.04	0.06	0.985366
September	2.2	1.46	0.74	0.663636
October	3.3	2.07	1.23	0.627273
November	5.8	3.31	2.49	0.57069
December	7.3	2.88	4.42	0.394521
	60	**33.98**	2.168333	0.599813

The results of this exercise clearly show that had a decision maker relied solely on the annual precipitation or forage production they would have determined an insufficient amount of loss (35% departure) from what the site would normally produced in a normal precipitation year. By compiling QFP estimates it is revealed that the April – June quarter had a 50% departure from normal in terms of QFP. This is a sufficient departure to warrant payment under the USDA= FSA program. On the other hand, the remaining quarters showed that departure from normal was less than 50%. This kind of analysis would assure payment during times when forage losses were actually incurred and eliminate overpayment when it is not allowing for a more efficient use of federal support services and funds.

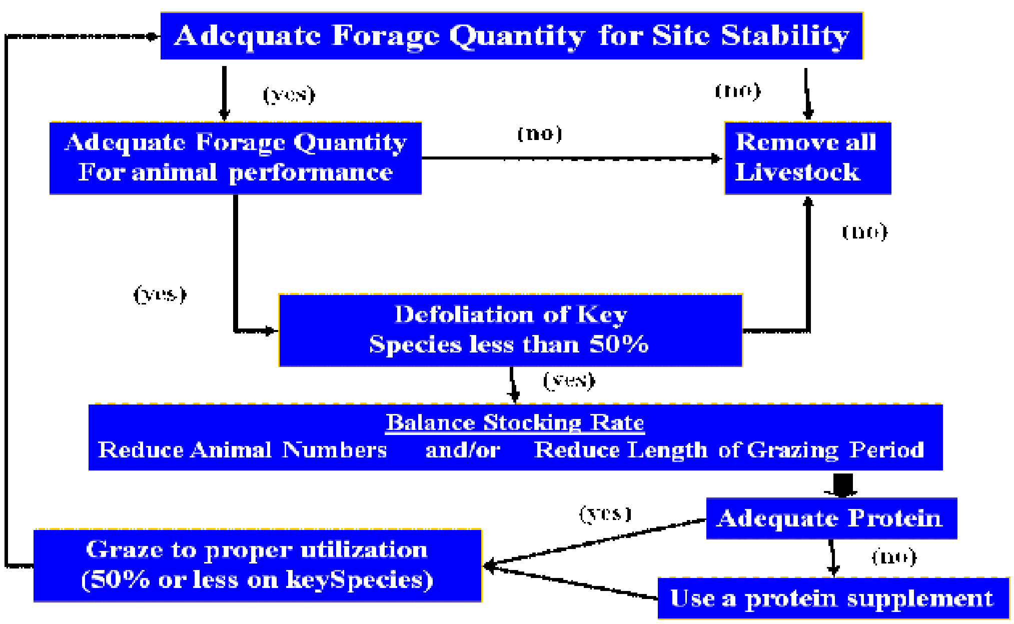
Quarterly and Total Mean Annual Precipitation (MAP), 2009 precipitation, estimated MAP Quarterly Forage Production (QFP, lbs DM/acre), and 2009 QFP estimates with associated percent departures.

Quarter	Quart. MAP (in)	2009 Precip. (in)	Percent Departure from Normal Precip.	Quart. MAP Forage Production (lbs. DM/acre)	2009 Quart. Forage Production (lbs DM/acre)	Percent Departure in Forage Production
January - March	20.5	12.1	41%	4,506	2,936	35%
April - June	13.1	4.8	63%	3,130	1,577	50%
July - September	10	8.9	11%	2,553	2,350	8%
October - December	16.4	8.3	49%	3,743	2,229	40%
Annual Total	60	34	43%	13,932	9,092	35%

Decision Support Tool 2.

One of the most difficult and frustrating things for producers during drought is to stand by and watch their herd slowly starve to death. The second most difficult thing is making the decision to begin destocking. The decision to "hang-on" just a little longer is so tempting because we know rain is "just around the corner" and then everything will be "ok". Unfortunately, many producers hang-on too long and the result is severely damaged range and pasturelands that are slow to recover when rains do come back, and malnourished or dead livestock. One reason for this is our inability to forecast forage production on a continual basis. If a produce could measure rainfall and then estimate, with some level of accuracy, the potential amount of forage they would have over a given period, they would be able to be proactive in their stocking decisions in the face of a developing drought. A continual estimate of forage production would allow them to forecast when forage would run out and allow them to make sound decisions to destock before resources were negatively impacted. The Daily Forage Production Quotient developed here for each island is such a tool.

The DFPQ would be used in the first two boxes of the following decision flow chart to 1) determine if there is enough forage for site stability (providing adequate ground cover); and 2) to determine if there is enough forage to maintain animal performance (balance stocking rate). The first rule is that forage production should be half or better of the mean annual production potential for a given range or pasture site. The second rule is that, without destocking, grazing should remove no more than 50% of the total available forage (take half, leave half) without compromising site stability and limiting animal performance.



A flow chart for grazing management decisions during drought (adapted from Reece et al. 199. Drought Management on Range and Pastureland: A handbook for Nebraska and South Dakota. Nebraska Cooperative Extension publication EC91-123. University of Nebraska – Lincoln. Pp 23.).

In accordance to the first two decision points in the above decision flow chart the following decision support tool was developed. The tool is designed to allow producers to answer key questions that lead to a proper decision in balancing their stocking rate to maintain site stability and animal performance. The tool requires knowledge of the MAP for the area which can be obtained either through their personal records or by finding a NOAA-National Weather Service weather station near their operation. Using the monthly average precipitation values and the appropriate Daily Forage Production Quotient for their island the producer could develop a table of estimated daily forage production by each month of the year as a reference. As each month's precipitation is recorded (or it could be estimated daily, weekly, or longer depending on the desire of the producer) an estimate of the forage availability for the next interval can be calculated allowing for stocking rate adjustments as conditions change.
The following example shows how the tool works:

Example parameters: A 400 acre ranch in the Kamuela area is stocked normally with 200 cow/calf pairs (AU). Annual forage production averages 13,932 lbs DM/acre with a MAP of 60 inches (using the MAP and 2009 rainfall for the Kamuela station in the previous section). Note: for this example the table has been filled in completely. The producer would calculate the values as with each month.

Table of estimated Daily Forage Productivity (DFP = lbs DM/acre/day) by month using site MAP and the DFPQ (3.2 lbs DM/acre/day/inch of rain): **YEAR_2009__**

Month	Monthly Average Precipitation (inches)	[1]Estimated Average Daily Forage Productivity (lbs DM/acre/day)	Current Monthly Precipitation (inches)	[1]Estimated Daily Forage Productivity (lbs DM/acre/day)
January	6.6	**21.1**	2.9	**9.3**
February	6.0	**19.2**	5.3	**17.0**
March	7.9	**25.3**	3.9	**12.5**
April	6.9	**22.1**	2.5	**8.0**
May	4.0	**12.8**	0.8	**2.6**
June	2.2	**7.0**	1.5	**4.8**
July	3.7	**11.8**	3.4	**10.9**
August	4.1	**13.1**	4.0	**12.8**
September	2.2	**7.0**	1.5	**4.8**
October	3.3	**10.6**	2.1	**6.7**
November	5.8	**18.6**	3.3	**10.6**
December	7.3	**23.4**	2.9	**9.3**
Annual Total	60.0		34.1	

[1]Note values in these cells are calculated from an internal formula (DFPQ x monthly precipitation).

1. What is the total number of acres grazed? 400 .

2. Under normal conditions what is the estimated total forage production for the month of interest? (400 acres x average DFP for month x 30 days)? 253,200 lbs DM .

3. For the current rainfall received what is the estimated total forage production (400 acres x current DFP for month x 30 days)? 111,600 lbs DM .

> (NOTE: 111,600 lbs DM will provide only 10.7 days of grazing for 200 AUs; 111,600 x 0.5 x 200 AU x 26 lbs DM/AU)

Maintain Site Stability:

4. Is the amount in 3 at least half of value in 2 (divide the value in 3 by the value in 2; if the result is ≥ 0.5 then enter a yes; if it < 0.5 then enter no)? (result is 0.44) No .

If the answer to 4 is no then destocking to balance stocking rate is critical to maintain site stability.

If the answer to 4 is yes then proceed to part 5.

Maintain Animal Performance:

5.

> 5a. Calculate daily forage demand of herd (#AUs x 26 lbs DM): ________________.
>
> 5b. Determine the number of days available forage will support herd (50% of value in 3 / value in 5a):____.

5. Is the forage availability sufficient to meet the forage demand of the current number of AUs for 30 days or more? ____.
(note if yes then graze to 50% of the available forage; if no then destock to balance forage demand with availability)

(Note: the following example shows how a producer can project forage availability following a rainfall event)

Project Forage Availability

1. Amount of rainfall received? 1.5 inches .

2. Calculate Daily Forage Productivity (DFPQ x inches of rain): 4.8 lbs DM/acre/day.
   Note: DFPQ for Big Island is 3.2 lbs DM/acre/day/inch of rain
   DFPQ for Kauai is 5.2 lbs DM/acre/day/inch of rain
   DFPQ for Maui is 6.6 lbs DM/acre/day/inch of rain

3. Calculate Forage Production for desired period (i.e. 15 days; 30 days; value in 2 x # days): 144 lbs/DM/acre.

4. Calculate Total Forage Production for grazed Acreage (value in 3 x # acres): 57,600 lbs DM

5. Calculate the number of days this production will support herd (value in 4 x 0.5 / 26 lbs/AU/day): 5.5 days of grazing.

Summary

The two main deliverables for this project are the rain and forage production indices and the decision support tools. The data collected on this project allowed for the development of two types of indices that will support practical and sound grazing management decisions. The Quarterly Forage Production indices will assist with the determination of the effect of drought on forage resources for the USDA-FSA NAP-Forage program. The Daily Forage Productivity Quotient will allow producers to become proactive in their management of forage resources during a drought. It will allow them to forecast forage availability for a specified period of time and will aid in determining if forage resources are sufficient to first maintain site stability and then to maintain animal performance. These decision support tools will be disseminated via CTAHR Extension publications and the Hawaii Rangelands Website.