Integrating Legumes with Grass to Improve Forage-Livestock Systems

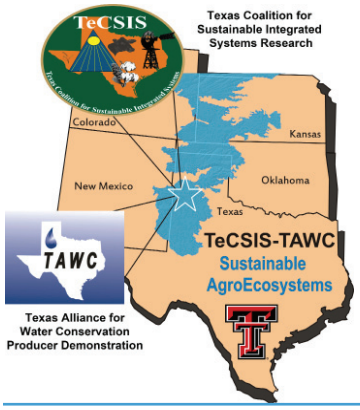
One can't talk about agriculture in the Texas High Plains without including "water" in the same sentence. The Ogallala Aquifer, which has kept ag production humming for nearly a century, is running low. Agriculture in the Texas Panhandle and Southern Plains is adapting to decreased water availability.

For over two decades, researchers and producers across the Texas High Plains have been developing integrated crop/livestock production systems that address the growing need for water conservation, while keeping soils fertile, crop yields profitable, cattle production thriving, and surrounding communities viable.

Funded through nearly $1.5 million in Southern SARE Research & Education, Large Systems, and Graduate Student grants, the results showcase long-term alternative production systems, and how those results are being translated into practical field production practices and sustainable agriculture applications.

This model of sustainable agroecosystems in the Texas High Plains is changing the face of agriculture in the region and helping to conserve water, improve soil health, boost ag profits and keep the High Plains region thriving for generations to come.

This bulletin looks at integrating legumes with grasses to improve the profitability of forage-livestock systems while minimizing irrigation usage to preserve water.



Cattle grazing on OWB. Photo credit: Texas Tech University

Over the past century, agriculture on the Texas High Plains has evolved into a $20 billion-plus industry centered largely on cotton and finishing beef cattle in feedlots.

Agriculture was made possible with fertile soils, cheap energy and fertilizers, and irrigation water from the Ogallala Aquifer – a crucial, but finite resource deep below the soil surface stretching from South Dakota to the Texas Panhandle.

With energy and other resource costs rising, and water declining in the Ogallala Aquifer, farmers are at a crossroads: Continue current unsustainable practices, or make cropping choices that conserve energy, improve soil and prolong the use of water remaining in the Ogallala.

Taking a "systems research" approach, Texas Tech University researchers – backed by over a decade of producer-driven field studies -- have compared cotton monoculture to diversified crop/livestock systems. What they have found is that systems based on or inclusive of forages and livestock require less water for irrigation and livestock use than systems based entirely on row crops.

Research continues at the Texas Tech New Deal Research Station with field trials pertaining to the integration of forages and livestock into a predominant row-crop region as a means of reducing water extraction from the Ogallala Aquifer, building soil organic matter, stabilizing soil from wind erosion, and diversifying income.

Following severe drought in the Texas High Plains in 2011 and 2012 and pasture recovery in 2013, grazing trials were restarted in 2014. A basic steer grazing

trial was conducted from 2014-2016 comparing a grass-only system of Old World Bluestem (OWB) receiving nitrogen fertilizer to an alternative (and hypothetically more sustainable) grass-legume system for animal productivity and water use efficiency.

The study also included grazing some native and teff pastures, but were used in minor amounts and didn't have an overall impact on the results.

Research Summary

Research results showed that steers gained more weight, and gained it more quickly, grazing a grass-legume system of OWB, alfalfa, and yellow sweetclover, compared to the OWB alone. In addition, the grass-legume system demonstrated a lower water footprint. These trials satisfied the hypothesis that including legumes with drought-tolerant grasses can improve animal productivity at low water input.

Research Objectives

The three-year grazing trial (2014-2016) was the basis for graduate student research on water use efficiency of cattle production and legume composition and forage availability. As the Ogallala Aquifer decline further limits irrigation, the goal is to identify water-efficient forage systems while keeping cattle production in the Texas High Plains region profitable.

Alfalfa in bloom. Photo credit: Texas Tech University

Researchers employed two innovations to test their hypothesis: Introducing alfalfa and yellow sweetclover into OWB; and creating a limited-acreage "protein bank", consisting mostly of alfalfa, which was rotationally grazed on a limited basis.

The novel aspects of the research challenged the notion that alfalfa is a high water use crop. "That is true when managed as a hay crop when pushed to its high-yield potential," said forage systems researcher Chuck West. "The other face of alfalfa is that it is a very deep-rooted, drought-resilient plant which can lay dormant during dry summers and recover after periodic rains. The soils of the Texas High Plains favor such a crop."

The research also targeted legumes for their low water needs as high-protein forages that can be integrated into grasses to boost the liveweight gain in cattle with little to no increase in irrigation for the entire grazing system.

Research Results

Researchers limited the irrigation supply to the test pastures over the three years: 8 inches to the grass system, and 7 inches to the grass-legume, averaged over the whole system. They then measured the water footprint (groundwater used per pound of weight gain in the cattle) and found that it took around 30 percent less water to produce a pound of beef liveweight gain when adding legumes to the pasture system. When considering only pumped groundwater, the comparison was 287 gallons of water per pound of gain in the legume-grass system vs. 395 gallons of water per pound of gain in the grass-only system.

Researchers determined that 9 to 12

Cattle grazing on a legume/grass mix. Photo credit: Texas Tech University

inches of irrigation were reasonable targets if grazing-season rainfall is less than average or above average but unevenly distributed across the season. By comparison, the amount of irrigation applied annually to cotton averages around 12 inches and for corn, around 18 inches.

"Our realization of 7-8 inches of irrigation indicates progress in providing a viable land-use option for cropland whose irrigation systems can no longer provide irrigation at high-yield levels," said West.

Over the three-year trial, average weight gain for steers was 2.06 pounds per day in the grass-legume system, compared to only 1.74 pounds per day in the grass-alone system. The season-long weight gain per area was 188 pounds per acre and 118 pounds per acre, respectively.

In addition, forage quality averaged 14.4 percent crude protein content in the grass-legume system compared to 7 percent for the grass-alone system. This, say the researchers, explains the greater productivity of cattle on the grass-legume system.

Final Outcomes

The take-home message is that boosting forage quality by adding legumes to drought-tolerant grasses while keeping water inputs low boosts the sustainability of water use in a beef grazing system.

Researchers are currently conducting an economic analysis of the grazing trial data to round out the picture of sustainability of water use for beef cattle grazing in legume-enhanced pastures.

Studies at Texas Tech University have emphasized the transition to low-irrigation management systems that address trends that are shaping the future of Southern High Plains agriculture: Fewer overall irrigated acres and increased acres of limited-acreage, high-value crops; improvements in water use efficiency of major row crops; partial replacement of irrigated row crops with drought-tolerant grasses and legumes or dryland crops; increased use of water management technologies; and warmer temperatures leading to greater evaporative demand and more droughts.

Details of the study are outlined in the SSARE Research & Education Grant LS14-261, "Long-term Agroecosystems Research and Adoption in the Texas Southern High Plains – Phase III."

High Plains Water Conservation Resources

General Information

Texas Coalition for Sustainable Integrated Systems (TeCSIS)
http://www.orgs.ttu.edu/forageresearch/

Texas Alliance for Water Conservation
http://www.depts.ttu.edu/tawc/

TAWC Solutions
http://www.tawcsolutions.org/

Texas Water Development Board
http://www.twdb.texas.gov/groundwater/aquifer/majors/ogallala.asp

Texas High Plains Water District
http://www.hpwd.org/

Ogallala Aquifer Program
http://ogallala.tamu.edu

Ogallala Water Coordinated Agriculture Project (USDA-NIFA)
http://www.ogallalawater.org

Publications

High Plains Water Conservation Bulletin No. 1: Water Conservation in the Texas High Plains

High Plains Water Conservation Bulletin No. 2 : Sustainable Crop/Livestock Systems in the Texas High Plains Phase I

High Plains Water Conservation Bulletin No. 3: Sustainable Crop/Livestock Systems in the Texas High Plains Phase II

High Plains Water Conservation Bulletin No. 4: Sustainable Crop/Livestock Systems in the Texas High Plains Phase III

High Plains Water Conservation Bulletin No. 5: Diversifying in the Texas High Plains

High Plains Water Conservation Bulletin No. 6: Agroecoystems Economics in the Texas High Plains

High Plains Water Conservation Bulletin No. 7: Soil Quality of Integrated Crop/Livestock Systems

High Plains Water Conservation Bulletin No. 8: Texas Alliance for Water Conservation

High Plains Water Conservation Bulletin No. 9: Water Use of Old World Bluestems in the Texas High Plains

High Plains Water Conservation Bulletin No. 10: Cover Crops and Cotton in the Texas High Plains

High Plains Water Conservation Bulletin No. 11: Agroecosystems Research in the Texas High Plains: Graduate Student Studies

High Plains Water Conservation Bulletin No. 12: The Performance of Cover Crops in Minimally Tilled Forage-based GrazingSystems

Grant Projects

LS17-286 Long-term Agroecosystems Research and Adoption in the Texas Southern High Plains: Phase III

LS14-261 Long-term Agroecosystems Research and Adoption in the Texas Southern High Plains: Phase II

LS11-238 Long-term Agroecosystems Research and Adoption in the Texas Southern High Plains: Phase I

LS10-229 Integrated Crop and Livestock Systems for Enhanced Soil Carbon Sequestration and Microbial Diversity in the Semiarid Texas High Plains

LS08-202 Crop-livestock Systems for Sustainable High Plains Agriculture

LS02-131 Forage and Livestock Systems for Sustainable High Plains Agriculture

LS97-082 Sustainable Crop/Livestock Systems in the Texas High Plains

GS18-196 Effects of Cumulative Cattle Trampling on Soil Bulk Density and Infiltration of Rain Water on an Annual Forage Crop Pasture

GS15-152 Evaluation of Winter Annual Cover Crops Under Multiple Residue Managements: Impacts on Land Management, Soil Water Depletion, and Cash Crop Productivity

GS07-056 Allelopathic effects of small grain cover crops on cotton plant growth and yields

GS02-012 Optimizing Water Use for Three Old World Bluestems in the Texas High Plains

Journal Articles

Acosta-Martinez, V., T.M. Zobeck, and V.G. Allen. 2004. Soil Microbial, Chemical and Physical Properties in Continuous Cotton and Integrated Crop-Livestock Systems. *Soil Society of America Journal* 68:1875-1884.

Allen, V.G, C.P. Brown, R. Kellison, E. Segarra, T. Wheeler, P.A. Dotray, J.C. Conkwright, C.J. Green, and V. Acosta-Martinez. 2004. Integrating Cotton and Beef Production to Reduce Water Withdrawal from the Ogallala Aquifer in the Southern High Plains. *Agronomy Journal* 97:556-567.

Allen, V.G., C.P. Brown, R. Kellison, E. Segarra, T. Wheeler, P.A. Dotray, J.C. Conkwright, C.J. Green, and V. Acosta-Martinez. 2005. Integrating Cotton and Beef Production to Reduce Water Withdrawal from the Ogallala Aquifer. *Agronomy Journal* 97:556-567.

Philipp, D., V.G. Allen, R.B. Mitchell, C.P. Brown, and D.B. Wester. 2005 Forage Nutritive Value and Morphology of Three Old World Bluestems Under a Range of Irrigation Levels. *Crop Science* 45:2258-2268.

Philipp, D., C.P. Brown, V.G. Allen, and D.B. Wester. 2006. Influence of Irrigation on Mineral Concentrations in Three Old World Bluestem Species. *Crop Science* 46:2033-2040.

Allen, V.G., M.T. Baker, E. Segarra, and C.P. Brown. 2007. Integrated Irrigated Crop-Livestock Systems in Dry Climates. *Agronomy Journal* 99:346-360.

Philipp, D., V.G. Allen, R.J. Lascano, C.P. Brown, and D.B. Wester. 2007. Production and Water Use Efficiency of Three Old World Bluestems. *Crop Science* 47:787-794.

Marsalis, M.A., V.G. Allen, C.P. Brown, and C.J. Green. 2007. Yield and Nutritive Value of Forage Bermudagrasses Grown Using Subsurface Drip Irrigation in the Southern High Plains. *Crop Science* 47:1246-1254.

Allen, V.G., C.P. Brown, E. Segarra, C.J. Green, T.A.Wheeler, V. Acosta-Martinez, and T.M. Zobeck. 2008. In Search of Sustainable Agricultural Systems for the Llano Estacado of the U.S. Southern High Plains. *Agriculture, Ecosystems and Environment* 124:3-12.

Acosta-Martinez, V., S. Dowd, S. Yung, and V. Allen. 2008. Tag Encoded Pyrosequencing Analysis of Bacterial Diversity in a Single Soil Type as Affected by Management and Land Use. *Soil Biology & Biochemistry* 40:2762-2770.

Dudensing, J., J. Johnson, P. Johnson, and C. Villalobos. 2008. Grazing Alternatives in the Face of Declining Groundwater: A Case from the Southern High Plains of Texas. *Texas Journal of Agriculture and Natural Resources*

21:60-72.

Maas, S.J., and N. Rajan. 2008. Estimating Ground Cover of Field Crops Using Medium-resolution Multispectral Satellite Imagery. *Agronomy Journal* 100(2):320-327.

Wheeler-Cook, E., E. Segarra, P. Johnson, J. Johnson and D. Willis. 2008. Water Conservation Policy Evaluation: The Case of the Southern Ogallala Aquifer. *Texas Journal of Agriculture and Natural Resources* 21:89-102.

Johnson, J., P. Johnson, E. Segarra, and D. Willis. 2009. Water Conservation Policy Alternatives for the Ogallala Aquifer in Texas. *Water Policy* 11:537-552.

Acosta-Martinez, V., G. Burrow, T.M. Zobeck, and V.G. Allen. 2010. Soil Microbial Communities and Function in Alternative Systems to Continuous Cotton. *Soil Science Society of America Journal* 74:1181-1192.

Acosta-Martinez, V., Bell, C.W., Morris, B.E.L., Zak, J., and Allen, V.G. 2010. Long-term Soil Microbial Community and Enzyme Activity Responses to an Integrated Cropping-Livestock System in a Semi-arid Region. *Agriculture, Ecosystems and Environment* 137:231-240.

Acosta-Martinez, V., Dowd, S.E., Sun, Y., Wester, D., and Allen, V.G. 2010. Pyrosequencing Analysis for Characterization of Soil Bacterial Populations as Affected by an Integrated Livestock-Cotton Production System. *Applied Soil Ecology* 45:13-25.

Maas, S.J., and N. Rajan. 2010. Normalizing and Converting Image DC Data Using Scatter Plot Matching. *Remote Sensing* 2(7):1644-1661.

Rajan, N., S.J. Maas, and J.C. Kathilankal. 2010. Estimating Crop Water Use of Cotton in the Texas High Plains. *Agronomy Journal* 102:1641-1651.

Allen, V.G., C. Batello, E.J. Berretta, J. Hodgson, M. Kothmann, X. Li, J. McIvor, J. Milne, C. Morris, A. Peeters, and M. Sanderson. 2011. An International Terminology for Grazing Lands and Grazing Animals. *Grass and Forage Science* 66:2-28.

Zilverberg, C.J., P. Johnson, J. Weinheimer, and V.G. Allen. 2011. Energy and Carbon Costs of Selected Cow-calf Systems. *Rangeland Ecology and Management* 64(6):573-584.

Zobeck, T.M., V.G. Allen, J.J. Cox, and D. Philipp. 2011. Variation of Soil and Plant Characteristics Among Old World Bluestem Species. *Agricultural Sciences* 2:347-356.

Davinic, M., L.M. Fultz, V. Acosta-Martinez, F.J. Calderon, S.B. Cox, S.E. Dowd, V.G. Allen, J.C. Zak, and J. Moore-Kucera. 2012. Pyrosequencing and Mid-infrared Spectroscopy Reveal Distinct Aggregate Stratification of Soil Bacterial Communities and Organic Matter Composition. *Soil Biology & Biochemistry* 46:63-72.

Allen, V.G., C.P. Brown, R. Kellison, P. Green, C.J. Zilverberg, P. Johnson, J. Weinheimer. T. Wheeler, E. Segarra, V. Acosta-Martinez, T.M. Zobeck, and J.C. Conkwright. 2012. Integrating Cotton and Beef Production in the Texas Southern High Plains I: Water Use and Measure of Productivity. *Agronomy Journal* 104:1625-1642.

Zilverberg, C.J., V.G. Allen, C.P. Brown, P. Green, P. Johnson, and J. Weinheimer. 2012. Integrating Cotton and Beef Production in the Texas Southern High Plains II: Fossil Fuel Use. *Agronomy Journal* 104: 1643-1651.

Trojan, S, and C. West. 2012. Conserving Water and Maintaining Economic Viability by Grazing Introduced Perennial Grasses. *Rangeland Issues* 1(3):1-7. National Ranching Heritage Center, Texas Tech University, Lubbock.

Mitchell, D., P.N. Johnson, V. Allen, C. Zilverberg. 2013. Integrating Cotton and Beef Production in the Texas Southern High Plains: A simulation approach. Southern Agricultural Economics Association Annual Meeting, Orlando, Florida (selected paper).

Cui, Song, V.G. Allen, C.P. Brown, and D. B. Wester. 2013. Growth and Nutritive Value of Three Old World Bluestems and Three Legumes in the Semi-arid Texas High Plains. *Crop Science* 53:1-12.

Johnson, P., J. Zilverberg, V.G. Allen, J. Weinheimer, C.P. Brown, R. Kellison, and E. Segarra. 2013. Integrating Cotton and Beef Production in the Texas Southern High Plains III: An Economic Evaluation. *Agronomy Journal* 105:929-937.

Davinic, M., J. Moore-Kucera, V. Acosta-Martinez, J. Zak, and V. Allen. 2013. Soil Fungal Groups' Distribution and Saprophytic Functionality as Affected by Grazing and Vegetation Components of Integrated Cropping-Livestock Agroecosystems. *Applied Soil Ecology* 66:61-70.

Fultz, L.M., J. Moore-Kucera, T.M. Zobeck, V. Acosta-Martinez, and V.G. Allen. 2013. Aggregate Carbon Pools After 13 Years of Integrated Crop-Livestock Management in Semi-arid Soils. *Soil Science Society of America Journal* 77(5):1659-1666.

Li, Y., V.G. Allen, F. Hou, J. Chen, and C.P. Brown. 2013. Steers Grazing a Rye Cover Crop Influence Growth of Rye and No-till Cotton. *Agronomy Journal* 105: 1571-1580.

Li, Y., V.G. Allen, J. Chen, F. Hou, C.P. Brown, and P. Green. 2013. Allelopathic Influence of Wheat or Rye Cover Crop on Growth and Yield of No-till Cotton. *Agronomy Journal* 105: 1581-1587.

Fultz, L.M., J. Moore-Kucera, T.M. Zobeck, V. Acosta-Martinez, D.B. Wester, and V.G. Allen. 2013. Organic Carbon Dynamics and Soil Stability in Five Semi-arid Agroecosystems. *Agriculture, Ecosystems and Environment* 181:231-240.

Benson, A., and C. Zilverberg. 2013. A Bioeconomic Model for Sustainable Grazing of Old World Bluestem Under Uncertainty. *Natural Resources* 4:362-368.

Rajan, N., S. Maas and C. Song. 2013. Extreme Drought Effects on Carbon Dynamics of a Semi-arid Pasture. *Agronomy Journal* 105:1749-1760.

Zilverberg, C.J., C.P. Brown, P. Green, M.L. Galyean, and V.G. Allen. 2014. Integrated Crop-Livestock Systems in the Texas High Plains: Productivity and water use. *Agronomy Journal* 106 3:831-843.

Cui, Song, C.J. Zilverberg, V.G. Allen, C.P. Brown, J. Moore-Kucera, D.B. Wester, M. Mirik, S. Chaudhuri, and N. Phillips. 2014. Carbon and Nitrogen Responses of Three Old World Bluestems to Nitrogen Fertilization or Inclusion of a Legume. *Field Crops Research* 164:45-53.

Zilverberg, C.J., and V.G. Allen. 2014. Technical Note: Repeated Grazing Affects Quality and Sampling Strategies of 'WW-B.Dahl' Old World Bluestem. *The Texas Journal of Agriculture and Natural Resources* 27:84-87.

Zilverberg, C., P. Brown, P. Green, V. Allen, and M. Galyean. 2015. Forage Performance in Crop-Livestock Systems Designed to Reduce Water Withdrawals from a Declining Aquifer. *Rangelands* 37:55-61.

Baxter, L.L., C.P. West, C.P. Brown, and P.E. Green. 2017. Nondestructive Determination of Legume Content in Grass-legume Pastures. *Crop Forage Turfgrass Management* Vol. 3(1).

Baxter, L.L., C.P. West, C.P. Brown, and P.E. Green. 2017. Comparing Nondestructive Sampling Techniques for Predicting Forage Mass in Alfalfa-tall Wheatgrass Pasture. *Agronomy Journal* 109:2097-2106.

Baxter, L.L., C.P. West, C.P. Brown, and P.G. Green. 2017. Stocker Beef Production on Low-water Input Systems in Response to Legume Inclusion. I. Forage and animal responses. *Crop Science* 57:2294-2302.

Baxter, L.L., C.P. West, J.O. Sarturi, C.P. Brown, and P.G. Green. 2017. Stocker Beef Production on Low-water Input Systems in Response to Legume Inclusion. II. Water footprint. *Crop Science* 57:2303-2312.

West, C., D. Malinowski, and T. McLendon. 2017. Responses of Grassland Communities to Climate Changes in Texas and Oklahoma. Proceedings of 71st Southern Pasture and Forage Crop Improvement Conference. 5-7 June, Knoxville, TN.

Cano, Amanda, A. Núñez, V. Acosta-Martinez, M. Schipanski, R. Ghimire, C. Rice, and C. West. 2018. Current Knowledge and Future Research Directions to Link Soil Health and Water Conservation in the Ogallala Aquifer Region. *Geoderma* 328:109-118.

Bhandari, Krishna B., C.P. West, and S.D. Longing. 2018. Fly Densities on Cattle Grazing 'WW-B.Dahl' Old World Bluestem Pasture Systems. *Texas Journal of Agriculture and Natural Ressources* 31:T1-T5.

Bhandari, K.B., C.P. West, S.D. Longing, C.P. Brown, and P.E. Green. 2018. Comparison of Arthropod Communities Among Different Forage Types on the Texas High Plains Using Pitfall Traps. *Crop Forage Turfgrass Management* Vol. 4(2).

West, C.P., and L.L. Baxter. 2018. Water Footprint of Beef Production on Texas High Plains Pasture. *Water International* 43:887-891.

Bhandari, K.B., C.P. West, V. Acosta-Martinez, J. Cotton, and A. Cano. 2018. Soil Microbial Communities, Enzyme Activities, and Total Carbon and Nitrogen as Affected by Diverse Grasses and Grass-alfalfa in Pastures. *Applied Soil Ecology* 132:179-186.

Bhandari, K.B., C.P. West, S.D. Longing, C.P. Brown, P.E. Green, and E. Barkowsky. 2018. Pollinator Abundances in Semi-arid Pastures as Affected by Forage Species. *Crop Science* 58:2665-2671.

Bhandari, K.B., C.P. West, and S.D. Longing. 2018. Canopy Communities of Arthropods in Response to Diverse Forages. *Agricultural & Environmental Letters* 3(1):180037.

Rudnick, D.R., S. Irmak, C.P. West, I. Kisekka, T.H. Marek, J.P. Schneekloth, D.M. McCallister, V. Sharma, K. Djaman, J. Aguilar, J.L. Chávez, M. Schipanski, D.H. Rogers, and A. Schlegel. 2018. Deficit Irrigation Management of Maize Above the High Plains Aquifer: A review. *Journal of American Water Resources Association.* [Accepted]

Xiong, V., C.P. West, C.P. Brown, and P.E. Green. 2019. Digital Image Analysis of Old World Bluestem Cover to Estimate Canopy Development. *Agronomy Journal.* [Accepted]

This bulletin was produced and published by the Southern Region of the Sustainable Agriculture Research and Education (SARE) program, and reviewed by Texas Tech University. This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, through Southern Sustainable Agriculture Research and Education, under sub-award number: LS14-261.

This bulletin was written by Candace Pollock-Moore, Southern Region SARE program, with reviews and revisions made by Chuck West of Texas Tech University TeCSIS. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Photos courtesy of Texas Tech University TeCSIS.

Funded by the USDA National Institute of Food and Agriculture (NIFA), Southern SARE operates under cooperative agreements with the University of Georgia, Fort Valley State University, and the Kerr Center for Sustainable Agriculture to offer competitive grants to advance sustainable agriculture in America's Southern region. USDA is an equal opportunity employer and service provider.