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Assessing Tribal College Priorities for Enhancing Climate Adaptation on Reservation Lands

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Abstract: On reservation lands, tribal colleges and universities (TCUs) are key to preparing indigenous communities to adapt to the effects of a changing climate. The original mission of TCUs, to improve access to higher education and to sustain the cultural heritage of indigenous people, facilitates close ties between TCU faculty and staff and the indigenous communities they serve. Since 1994, the land-grant status of TCUs allows access to limited federal funds in support of research, education, and outreach to improve food security, natural resource management, and rural quality of life, while expanding public access to higher education to underserved populations in remote rural areas. This study was designed to assess the priorities for enhancing climate adaptation on reservation lands. It summarizes the results of an assessment implemented at the 2016 Annual First Americans Land-Grant Consortium Conference. Study participants included faculty, administrators, outreach educators, support staff, and students representing 25 of the 37 TCUs in the United States. Results from this national assessment suggest that in order for TCUs to effectively meet the climate adaptation needs of indigenous communities, additional fiscal and human resource investments are necessary. Specifically, this includes fiscal support to enhance climate science teaching, research, and professional development programs. Additional goals include creating or expanding food-sovereignty programs, increasing community outreach education, investigating climate change impacts on water resource quality, access, and related ecological services, and exploring renewable and alternative energy opportunities.

Keywords: *higher education, outreach, climate resilience, land-grant, indigenous people, needs assessment, tribal lands, food sovereignty*

Indigenous communities in the United States are increasingly recognized as being among the most vulnerable to climate change impacts on water resources (IPCC 2012; Cozzetto et al. 2013; Bennett et al. 2014). Increasing global temperatures have adverse effects on reservation lands, impacting ecological and landscape health, economic livelihoods, water quality and quantity, and traditional and cultural practices (Doyle et al. 2013; Bennett et al. 2014). The Intergovernmental Panel on Climate Change (IPCC) suggests that the number of areas affected by drought and earlier snowmelt will likely increase, adversely affecting water supplies available for municipal, industrial, and recreational use, wildlife habitat, as well as energy and food production (IPCC 2012; Mankin et al. 2015). For tribal lands located in the western United States, climate impacts include extreme drought and/or flooding events (Dettinger et al. 2015). Increasing water demand to sustain steady urban population growth adds to the complexity of water supply and management issues tribes face (Cozzetto et al. 2013). Indigenous communities located in coastal regions currently face imminent displacement from their homes due to extreme weather events forced by climate change influences (Marino and Lazrus 2015).

Acutely aware of and often vocal about the threats posed by climate change, indigenous people continue to call for further investigation into the impacts of climate change on their communities. The National Congress of American Indians (2017)

continues to identify mitigating negative climate change impacts on indigenous communities among their top priorities. Even when ecological coherence exists, these impacts may be disparate at local and regional scales due to socio-cultural and political diversity among tribes (Bennett et al. 2014). Additionally, climate adaptation planning on tribal lands may require integrating indigenous traditional knowledge and worldviews with Western science (Cochran et al. 2013). This encourages community-specific climate impact investigations and adaptation initiatives, as well as collaborative efforts combining multiple forms of knowledge such as Western science and traditional knowledge.

Given the unique opportunities that tribal colleges and universities (TCUs) already provide, including culturally relevant research and education programming, TCUs may play a prominent role in enhancing the capacity of indigenous communities to adapt to the effects of a changing climate. These institutions primarily serve indigenous populations situated in rural, remote, and historically underserved communities that lack access to higher education (American Indian Higher Education Consortium 1999). The original mission of TCUs, to improve access to higher education and to sustain the cultural heritage of indigenous people, which honors an integrated worldview, facilitates close ties between TCU faculty and staff and the communities they serve (American Indian Higher Education Consortium 1999). Similar to the 1862 and 1890 land-grant institutions created by the Morrill Act, the 1994 TCUs are responsible to the indigenous communities they serve to improve quality of life through their teaching and outreach programs (Baird 1996). Furthermore, individual tribal governments create, charter, and control their own TCUs, thus are accountable for ensuring that TCUs address and support the unique and changing needs of sovereign tribal nations and reservation communities (American Indian Higher Education Consortium 1999).

TCUs are uniquely situated to educate and prepare professionals to enhance climate adaptation planning initiatives on reservation lands. Previous studies suggest that integrating traditional knowledge and cultural values into science education programs can enhance the engagement and retention of students with indigenous backgrounds (Semken 2005; Palmer et al. 2009; Reano and Ridgway 2015). Land-grant TCUs do this inherently through classroom instruction and extension outreach programs that promote self-efficacy, assist in identifying personal goals, enhance student skills, and encourage family relationships and connection with cultural practices (Keith et al. 2017). This ensures a culturally sensitive environment that also directly engages current and future TCU students, which has been shown to improve student success in the natural resource disciplines (Sloan and Welton 1997). This is particularly important given that Western science-based natural resource education programs often pose unique challenges to college students with indigenous backgrounds that include different ways of learning and knowing (Gervais et al. 2017).

Utilizing existing research and education frameworks that encourage community engagement may strengthen tribal capacity to assess climate change impacts, but the ability for TCUs to educate needed personnel may be limited. The student enrollment rate in science, technology, engineering, and math (STEM) fields at TCUs is rising. There was a 92% growth rate in these disciplines between the 2003-2004 and 2009-2010 academic years, yet only nine TCUs currently offer bachelor degrees in these fields (American Indian Higher Education Consortium 2012; Page 2017).

With nationally identified climate resilience research priorities (National Congress of American Indians 2017), it can be argued that TCUs have a land-grant responsibility to the Native American population to enhance tribal capacity to address these priorities. While this point is upheld considering TCUs depend on federal funding to operate, individual TCUs in collaboration with their respective tribes establish local research and education priorities (Nelson and Fry 2016). Acting at local levels to establish institutional priorities is not only an important component of tribal sovereignty and self-determination, but paramount in ensuring climate adaptation and resilience initiatives are relevant to local communities (Bennett et al. 2014).

Recognizing that TCUs have the potential to educate a climate literate workforce in a culturally

relevant manner, this study assesses TCU research and education priorities related to climate change adaptation on tribal lands at a national scale. Asking individuals most closely associated with TCUs to identify these priorities provides insight into critical higher education needs of indigenous communities that must be addressed in order to enhance tribal capacity for climate adaptation on tribal lands. This study aims to identify strategies and barriers related to TCU research, teaching, and outreach to support climate adaptation planning on reservation lands. It assesses priority trends that may be associated with an individual's role with a TCU or the location of a TCU. Understanding these priorities may help TCU personnel to direct their institutional fiscal and human resources more strategically to strengthen program areas that are needed most.

Methods

In order to better understand TCU needs, researchers developed a questionnaire to assess TCU priorities related to teaching, research, and outreach goals to support climate adaptation on tribal lands. The questionnaire featured 12 Likert-type scale questions encompassing a broad spectrum of potential goals and strategies to help support climate change adaptation on reservation lands. Critical to the development of these question items was the input of 1862 land-grant faculty with extensive research and outreach experience on reservation lands, in addition to input from faculty representing the First Americans Land-Grant Consortium (FALCON). Because very little baseline data or peer-reviewed studies are available on these topics as they relate to TCUs, this expertise ensured that question items were appropriate for corresponding TCUs with similar teaching, research, and outreach responsibilities. A panel of experts external to the study reviewed the resulting survey instrument, further refining the wording and sequencing of question items to improve readability and validity. The authors incorporated the suggested revisions into the final instrument.

We maintain the resulting question items, although specific, align with the recommendations resulting from previous climate change vulnerability and adaptation studies focused on indigenous issues (Cochran et al. 2013). These recommend conducting interdisciplinary analyses of impacts and honoring multiple forms of knowledge. Given the small size of the target population and challenges with accessing these individuals, the survey instrument was not pre-tested prior to its administration. To help overcome this limitation, we outline several data analysis strategies in the results section.

Researchers administered the assessment during a plenary session at the Annual FALCON Conference in November 2016. As a non-profit, professional association, sanctioned by the American Indian Higher Education Consortium (AIHEC) Board of Directors, FALCON represents the issues and interests of administrators, faculty, and staff at 1994 TCUs. TCU administrators, faculty, and students are uniquely situated to have insights into the needs and priorities of their institutions. Administering this assessment in partnership with FALCON members afforded a unique opportunity to solicit the participation of many TCUs across the United States, providing insight into Native Americans' higher education needs specific to localized climate adaptation strategies on reservation lands. This is considered a convenience sampling method, which limits our ability to ensure the sampled population is proportionately representative of each subset of the overall target population. While our target population was TCU faculty and administrators, we also include student responses in our results. We prioritized this sampling location to ensure national representation of TCU faculty and administrators.

Participants received a one-page questionnaire that featured 12 Likert-type scale question items. In order to gain additional insight from TCU faculty and administrators, we included a qualitative open-ended question in the survey that asked respondents to identify their top three priorities in addressing climate change and climate adaptation planning through teaching, research, and outreach. This question allowed participants to provide priorities in their own words that were not featured in the Likert-type scale question items. This also helps overcome uncertainty related to administering a survey that was not pre-tested on the target population. This question item helped

gain additional insight into the breadth of climate change adaptation issues that TCU faculty, staff, and students face. Two demographic question items were included to delineate if the respondent was a student or faculty, and identify their TCU's geographic location.

We presented an overview of the assessment, answered any questions from the participants, and asked them to complete the questionnaire and return it to us. Participants were instructed to omit their names or any identifying marks and to leave their completed questionnaires on conference tables. We secured the services of a proctor to gather and return to the authors completed surveys placed in a sealed envelope. This procedure ensured anonymity of the participants.

Data Limitations

There are very little baseline data available about our target population, yet such data can provide critical insight into the needs and priorities related to enhancing climate adaptation on reservation lands. A total of 59 (n = 59) respondents completed the questionnaire, representing 25 of the 37 (68%) TCUs in the United States. This sample of primary data is rare largely because there are challenges that exist with recruiting indigenous populations located in rural areas to participate in survey studies. The sample is reasonably representative of the perspectives of TCU faculty and administrators, however, given there are only about 450 TCU administrators and 1800 TCU faculty nationwide (American Indian Higher Education Consortium 2012). The overall sample size, n = 59, is relatively small, making statistically significant extrapolation and conclusions challenging even in the presence of substantive significance (Vogt 1993). Therefore, while a conventional threshold for statistical significance is a 95% Confidence Interval ($p < 0.05$), for this study we apply a 90% Confidence Interval ($p < 0.10$) when we used Pearson Chi-square tests to determine statistically significant correlations (Hawkes and Marsh 2004). Further, we maintain that a 90% Confidence Interval is an acceptable statistical significance threshold given the purpose of this study, indicating participants' demographic background has a 90% chance of correlating with their responses to other questions. We assert that the following statistical test results pertaining to correlation analysis, while informative, are exploratory. Additional data collection from an increased sample size is necessary to establish causal relationships and, in addition to the survey instrument described here, should include focus groups comprised of key informants. Such informants might represent the 12 of 37 TCUs not represented in this assessment and include a cross-section of TCU administrators, faculty, and students.

Results

The resulting data were analyzed using IBM Statistical Package for Social Sciences (SPSS) Version 24.0 as well as Microsoft Excel Version 14.7.3. Cronbach's coefficient alpha (CCA) was calculated to estimate internal consistency (instrument reliability) of the 12 Likert-type scale items. The Cronbach score for the 12 items was high ($r = 0.943$), indicating high internal consistency between variables (Carmines and Zeller 1979).

Of the 59 respondents, 12 worked in an administrative role, 12 were TCU extension outreach educators, 11 were support staff, 7 were faculty instructors, 7 were students, and 10 assessment participants chose not to respond to this particular question item. In order to use these demographic data for additional analysis, results for this question were aggregated as follows: individuals serving in an administrative capacity (Administrator + Support Staff, n = 23), individuals serving as faculty or educators (Extension Educator + Faculty Instructor, n = 19), and students (n = 7). We used this grouping strategy to identify whether a statistically significant correlation exists between respondents' roles at their respective TCU and their ranking of priority needs to enhance TCU capacity for conducting effective research, education, and outreach to support tribal climate adaption on reservation lands.

Based on data from the 2009-2010 American Indian Measures for Success Fact Book, a proportional distribution of our target population would be a 1:4 ratio of administrators to faculty (450:1800) (American Indian Higher Education Consortium 2012). Our sample population contains 23 administrators and 19 faculty members. While this could skew our overall priority results toward

perspectives of administrators, our results indicate that a statistically significant correlation only exists between TCU role and three of the 12 Likert-type scale item results. Correlations between demographic question items and priority question items are reported in each table.

Since the respondent pool represents 68% of the total TCUs and provides a relatively small number of participants per TCU, we aggregated responses two ways for the purposes of cross-correlation analysis. That is, we created a variable based on TCU location within established United States Geological Survey (USGS) water resource regions at a scale of hydrologic unit code (HUC) 2. This grouping was based on the assumption that general environmental and ecologic coherence exists among TCU populations located in the same water resource region. We assume that communities within similar environments share similar climate change impacts. Natural boundaries, such as water resource regions, offer more ecologic coherence as opposed to political boundaries, such as states. The percentage of TCUs located in each watershed is as follows: Missouri River (32.1%), Lower Colorado River (20.8%), Great Lakes (17.0%), Rio-Grande River (11.3%), Arkansas White Red (7.5%), Upper Mississippi River (3.8%), Souris-Red-Rainy (3.8%), and Pacific Northwest (3.8%).

We created a second aggregate variable by grouping TCU locations by general aridity in order to test correlations that may arise due to similar water related issues. This variable is an aridity scale based roughly on the average annual precipitation by water resource region (National Institute of Food and Agriculture 2015; NOAA National Weather Service 2017). The distribution of responses represented by this aggregate variable is as follows: arid (32.1%), semi-arid (35.8%), and non-arid (32.1%). These two new aggregate demographic variables were used to conduct a cross-correlation analysis of the data.

Respondents were asked to prioritize teaching, research, and outreach goals necessary to strengthen climate adaptation on tribal lands based on their respective experiences and perspectives. They were provided with 12 goals and instructed to assign priorities for each, using a Likert-type scale of 1 (very low priority) through 5 (very high priority). Mean scores were calculated for the 12 goals. The goals and ranked mean scores in descending order (highest to lowest priority) are illustrated in Table 1. Ranking these goals by mean score provides insight into the top priorities of TCUs from the perspective of faculty, staff, and students. All 12 goals were rated as high priority, each receiving a mean score of 3.5 or higher. Furthermore, six of the 12 goals had a mean score of at least 4.0, indicating a very high priority.

In order to conduct cross-correlation tests for statistical significance, we reduced participant responses to the 12 Likert-type question items from a five-item to a three-item scale. The resulting three-item scale is as follows: low priority (very low priority + low priority), neutral (same), and high priority (high priority + very high priority). Correlation results were determined by asymptotic significance (p) values resulting from a Pearson Chi-square test conducted for each question. As stated in *Data Limitations*, because the overall n-value of responses for this dataset is relatively small, and because this study is exploratory in nature, we used a Confidence Interval of 90% (significance rating of $p < 0.10$) rather than the conventional threshold of 95% ($p < 0.05$) to determine the statistical significance of our correlations (Hawkes and Marsh 2004).

Looking at the results of the Likert-type scale data (Table 1), the top two prioritized goals are: *increasing funding to tribal colleges to support teaching, research, and outreach focused on climate science, adaptation, and related subjects* ($m = 4.41$) and *supporting ongoing development of tribal college and tribal agency professionals* ($m = 4.36$). For the highest ranked goal, there was no significant correlation with respondent demographic information, indicating that this is the highest ranked goal regardless of TCU role or location. This is not the case for the second ranked goal in which respondents differed in their priority selection depending on both their TCU role and the general aridity of the watershed in which their TCU is located. Additional correlative results are reported alongside the ranked mean scores in Table 1.

While the Cronbach alpha score for the 12 items was high ($r = 0.943$), indicating high internal consistency between variables, it is not a measure of dimensionality. Recognizing that our

Table 1. Mean scores for tribal college and university (TCU) teaching, research, and outreach priorities and results of cross-correlations by TCU role and TCU location aridity.

Rank	Topic	Mean Score	Standard Deviation
1	Increasing funding to tribal colleges to support teaching, research, and outreach focused on climate science, adaptation, and related subjects	4.41	0.98
2	Supporting ongoing development of tribal college and tribal agency professionals	4.36[ab]	0.73
3	Enhancing tribal food security through improved water management on tribal lands	4.19	1.04
4/5	Strengthening tribal economies through innovative water resource uses	4.04[a]	1.10
4/5	Identifying adaptation strategies that complement ongoing traditional indigenous practices	4.04	0.97
6	Assessing the impacts of climate change on tribal lands and water resources	4.00[a]	0.98
7	Identifying climate adaptation strategies that address issues unique to tribal lands and water	3.99	0.97
8	Identifying traditional indigenous practices that inform tribal climate adaptation strategies	3.93[a]	1.09
9/10	Building/strengthening working relationships with 1862 land-grant university faculty and students	3.91	1.00
9/10	Assessing the impacts of climate change on tribal economies	3.91	1.12
11	Financing implementation of tribal climate adaptation plans	3.88	1.18
12	Exploring climate adaptation plans and strategies through annual tribal climate summits	3.65	1.21

Rating code: 1 = very low priority; 2 = low priority; 3 = neutral; 4 = high priority; 5 = very high priority.
[a] Significance = $p < 0.10$, TCU role (administration, faculty, student).
[b] Significance = $p < 0.10$, TCU location aridity (arid, semi-arid, non-arid).

12 Likert-type question items could be grouped into smaller dimensions, we organized the topics into four similar categories and calculated and ranked resulting mean scores. We determined these categories through a q-sorting method by creating a group comprised of three individuals external to the survey response group who represent tribal members interested in climate adaptation initiatives on reservation lands (Stephenson 1953). These individuals, while not directly representing our target sample group, shared similarities in their understanding of the 12 topics. Their grouping of the topics, therefore, reasonably related to that of our survey respondents. We provided these study participants with notecards outlining the 12 Likert-type scale question topics and asked them to sort similar topics into one of four groups. Each participant grouped the 12 topics similarly. These four groups are depicted in Figure 1. Mean scores and standard deviations were calculated for each topic group. While these new groups offer less detail than the individual 12 topics used in our analysis, the priorities more accurately represent the broader concepts. *Capacity building for tribal colleges and universities* is the group with the highest priority (m = 4.224), followed by *traditional knowledge uses* (m = 3.982), *land use impacts and adaptation strategies* (m = 3.960), and *tribal economic impacts* (m = 3.940), respectively. These results indicate that the 12 topics may provide sufficient dimension to be considered individually.

To test for correlations on these four topics, we

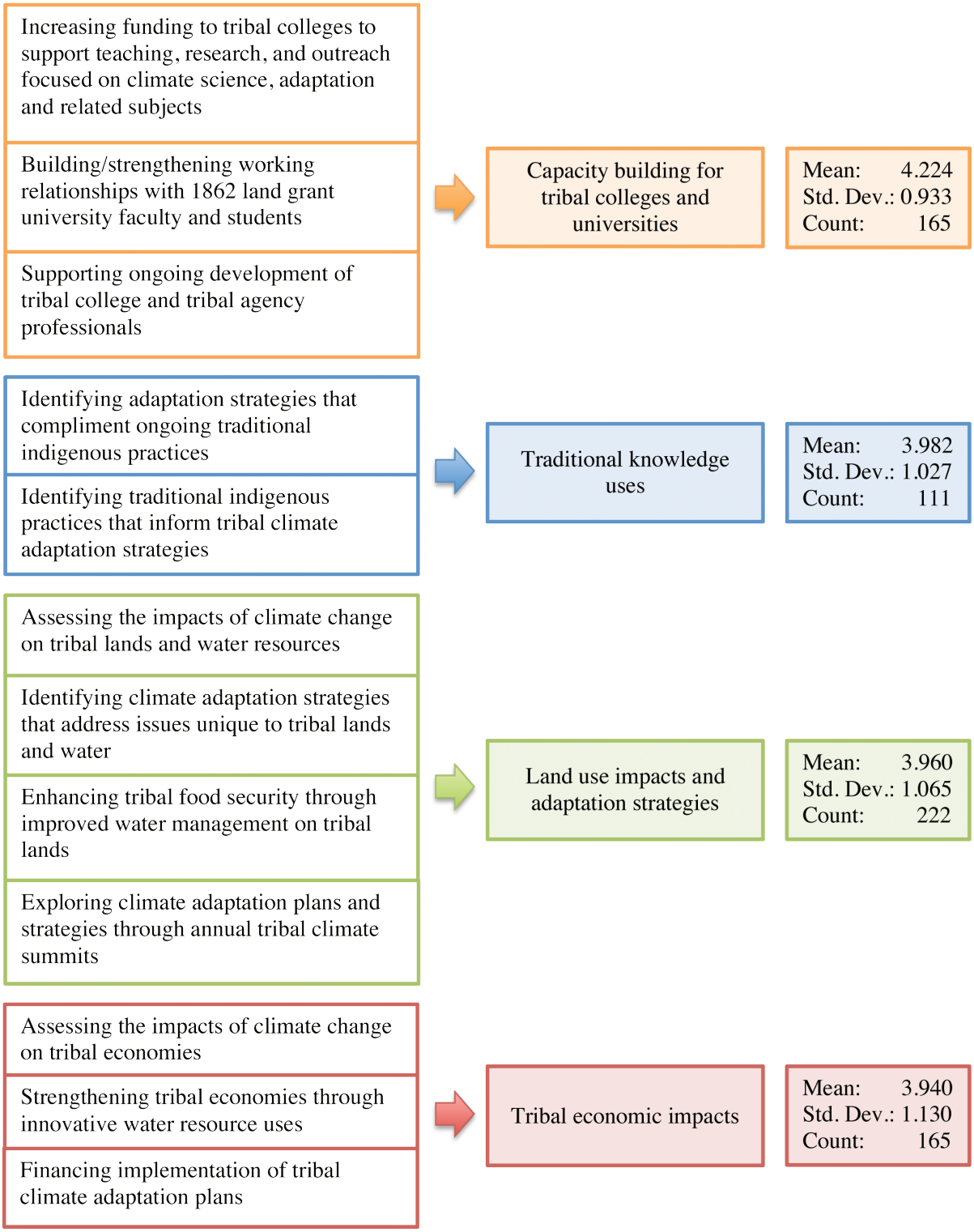

Figure 1. Tribal college and university (TCU) priorities for enhancing climate adaptation efforts on reservation lands. Dimensional grouping of original 12 Likert-type scale question items and associated mean ranking based on survey responses.

calculated the mean scores for each new group per survey, and assigned each response as either a priority (having a mean of 3.5 or greater on a scale of 1 to 5), or no priority (having a mean score of less than 3.5). For example, three topics make up the new group, *capacity building for tribal colleges and universities*. If a respondent indicated a 3, 4, and 5 on the original Likert-scale topics, respectively, their mean score for the new group would be a 4. This participant would then be assigned as indicating this new group is a *priority*. If a respondent indicated a 2, 3, and 3, respectively, their mean score for the new group would be 2.67 indicating *no priority* for this group. Researchers used the Pearson Chi-square test for correlations between these new groups and respondent demographic responses. Of these new groups, *land use impacts and adaptation strategies* is the only topic that has a significant correlation with an individual's role at his/her TCU ($p = 0.042$).

Participants were also asked to write their top three climate change adaptation priorities on tribal lands. This open-ended question item was included to probe for additional insight and to identify goals or needs that may have been inadvertently omitted from the 12 Likert-type scale question items featured in this study. Open-ended questions, as opposed to closed-ended and/or Likert-type scale questions, provide the opportunity to respond in detail and reduce potential for survey error associated with forcing participants to choose answers from a limited menu of choices (Patton 2002; Thorne 2016). In order to analyze these qualitative data, each response was *selectively coded* as belonging to one of six goals, illustrated in Table 2. That is, selective coding provided the most appropriate method to analyze these qualitative data, where one or more themes were developed to express the grouped content. Selective coding and enumerated grouped responses facilitated a cross-correlation analysis with participant demographic data (Miles et al. 2014).

The resulting six additional coded priorities or goals illustrate keywords and/or concepts cited most frequently. For example, nearly half (47.9%) of respondents described featured phrases or words relating to "food sovereignty and adaptive agriculture." These included terms such as "food sovereignty," "food security," "gardens," and "adaptive agriculture." Therefore, these written responses were coded as *food sovereignty and adaptive agriculture*. Only seven of the 104

Table 2. Additional tribal college and university (TCU) priorities to enhance climate adaptation on tribal lands and cross-correlations with TCU location by USGS Water resource region.

Rank	TCU Priorities to Support Climate Adaptation	N	Percent	Percent of Cases
1	Research Education Support and Capacity Building	24	24.2	50.0
2	Food Sovereignty and Adaptive Agriculture	23	23.2	47.9
3/4	Community Engagement and Collaboration	16	16.2	33.3
3/4	Water Quality and Quantity Issues [a]	16	16.2	33.3
5	Ecologic Interactions and Services	14	14.1	29.2
6	Renewable and Alternative Energy Opportunities	6	5.8	12.5
	Total	99*	100.0	206.3

[a] Significance $p < 0.10$, TCU location within USGS Water Resource Region (Missouri River, Lower Colorado River, Great Lakes, Rio-Grande River, Arkansas White Red, Upper Mississippi River, Souris-Red-Rainy, and Pacific Northwest)

*Note: The assessment resulted in 104 total individual written responses. These responses were reduced to 99 during data coding due to individual participants giving multiple responses belonging to a single one of the six coded priorities.

written responses did not directly relate to one of the six emergent coded groups. Since these few responses reasonably related to one or more of the six coded groups, however, they were categorized as belonging to one of these groups. For example, "It [climate adaptation] is mentioned [at our TCU] but not a priority," is one of these seven responses. Assuming that climate adaptation is mentioned but not as a priority may be due to limited resources available. Therefore, this response was categorized as belonging to a group of responses coded as *research education support and capacity building*.

Looking at the results shown in Table 2, a third of participants (33.3%) prioritized addressing water quality and/or quantity issues as a goal, which tied for third in overall ranking, along with increasing TCU engagement and collaboration with communities (33.3%). There is a statistically significant correlation ($p < 0.059$) between TCU location within a USGS water resource region (e.g., Missouri River, Lower Colorado River, Great Lakes, Rio-Grande River, Arkansas White Red, Upper Mississippi River, Souris-Red-Rainy, and Pacific Northwest) and whether or not respondents prioritized water resource issues in the open-ended question item as noted in Table 2. This indicates that participants differed in their responses depending on the location of their TCU within a water resource region. Because the open-ended question item generated multiple qualitative responses, even when similarly coded as groups, results for the cross-correlation between these group responses and demographic information are reported as percentages in Table 3, instead of by calculating asymptotic significance. While no statistical significance analysis was calculated for these correlative results, substantive significance may exist between participant responses and their demographic backgrounds.

Discussion

The results of this study suggest that TCU faculty, staff, and students who responded to this assessment perceive climate change adaptation as a priority for indigenous communities. They

Table 3. Cross-correlation analysis of additional tribal college and university (TCU) priorities by TCU role and TCU location aridity factor.

TCU Priorities to Support Climate Adaptation	TCU Role (%)			TCU Location (Aridity) (%)		
	Admin.	Faculty	Student	Arid	Semi-Arid	Non-Arid
Research Education Support and Capacity Building	60.0	33.3	40.0	50.0	62.5	38.5
Food Sovereignty and Adaptive Agriculture	40.0	66.7	60.0	43.8	62.5	38.5
Community Engagement and Collaboration	25.0	26.7	60.0	37.5	25.0	30.8
Water Quality and Quantity Issues	35.0	33.3	40.0	37.5	18.8	46.2
Ecologic Interactions and Services	30.0	40.0	0.0	18.8	31.3	46.2
Renewable and Alternative Energy Opportunities	15.0	6.7	20.0	18.8	6.3	7.7

Note: The results reported here represent the percentage of participants by TCU role and location (e.g., arid, semi-arid, or non-arid climates) whose responses to the open-ended question resonated with the goals as listed. Percentages do not add to 100% because respondents were asked to give multiple responses to this individual question item.

also indicate that TCUs lack the fiscal and human resources necessary to enhance the capacity of indigenous communities to implement effective climate change adaptation planning and action. In fact, when provided with a list of goals to rate or the opportunity to describe priority goals in their own words, respondents identified as their top priority increased funding for TCU research, education, and outreach to this end. When grouped with other topics related to capacity building of TCUs to contribute to climate adaptation initiatives, participants indicated this issue as the highest priority. This priority was also supported by participants when given the option to list open-ended priorities.

Many strategies exist to help TCUs build the capacity of indigenous communities to adapt to climate change, yet options are limited by the extreme funding constraints under which TCUs currently operate (Nelson and Frye 2016). TCUs currently receive the majority of their operating funding from Federal resources, yet receive only a fraction of the per-student funding compared to other federally-funded minority-focused colleges and universities (American Indian Higher Education Consortium 2012). The total number of TCUs and their enrollments continue to grow over time, but federal land-grant funding, accounting for inflation, has remained relatively stable since 1994 as illustrated in Figure 2. TCUs are forced to hire more adjunct faculty rather than full-time faculty in order to meet the growing student enrollment of their institutions (American Indian Higher Education Consortium 2012).

Our results from the open-ended question item suggest that participants in administrative roles (60.0%) were more likely to provide responses resonating with *research education support and capacity building* as compared to faculty (33.3%) and students (40.0%). This result is not surprising given that administrators of higher education institutions typically are more familiar with fiscal constraints than are faculty and students. However, this result may indicate an opportunity to increase communication concerning existing fiscal constraints to ensure that resources are expended

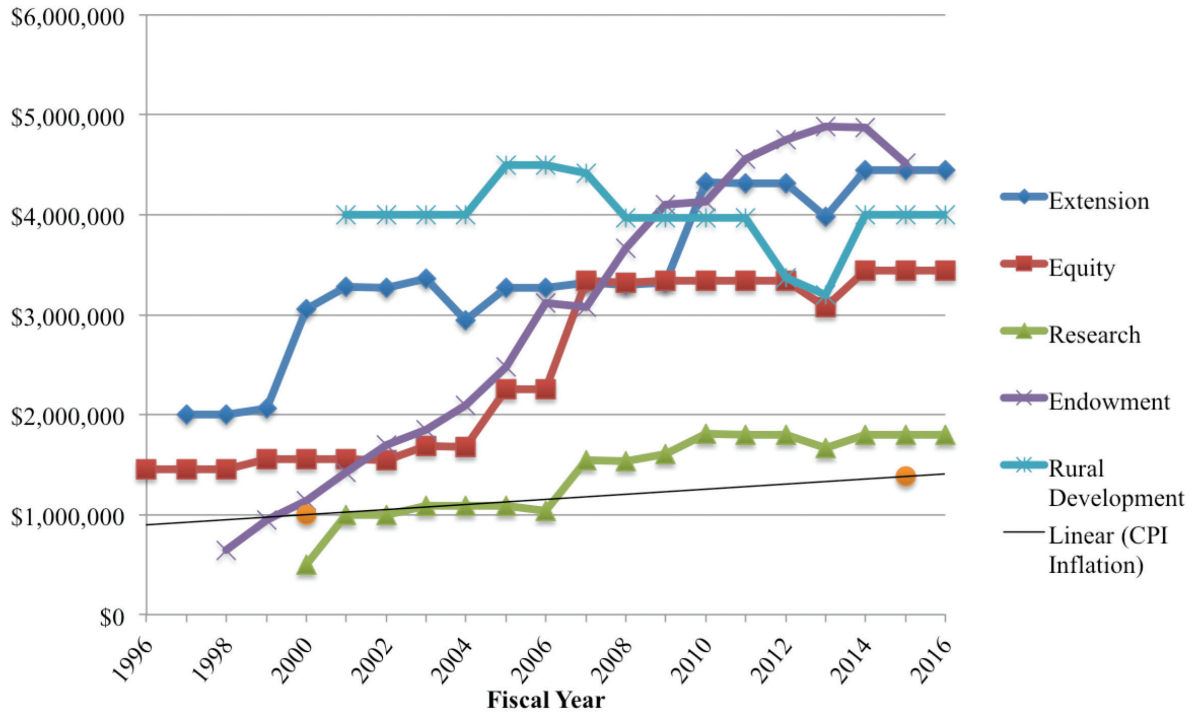

Figure 2. USDA National Institute of Food and Agriculture (2015) funding of 1994 tribal colleges and universities (TCUs). Equity funds support credited course instruction and related student services. Endowment refers to capacity funds; interest earned from endowment funds is distributed to TCUs based in part on student enrollment and is allocated to support the land-grant mission. The Community Facilities Program allocates rural development funds.

strategically to support the climate adaptation futures of reservations.

In the environmental sciences, it is imperative that research and education at the collegiate level be tailored to encompass a comprehensive analysis of climate adaptation issues unique to indigenous communities on reservation lands. TCU officials appear to be aware of this need by indicating community engagement and collaboration among their top priorities. This may likely remain one of the most challenging aspects of adaptation planning. However, through effective collaboration with tribal nations, researchers and educators can overcome these barriers (Chief et al. 2016). Given their proximity to remote and rural indigenous communities, existing relationships, and land-grant status, TCUs have the potential to be very important local resources to support indigenous climate adaptation initiatives.

Respondents in arid regions (37.5%) and non-arid regions (46.2%) were more likely than respondents in semi-arid regions (18.8%) to prioritize *water quality or quantity issues* in their open-ended priorities. While these two groups are on opposite sides of the aridity spectrum, water resource issues nevertheless are important. This may also suggest that TCUs in semi-arid environments are more likely to have their water quality and quantity needs met than those in arid and non-arid environments. Climate change effects on water resources threaten a range of reservation livelihoods from basic human health and survival to ecosystem services and large commercial agricultural operations (Cozzetto et al. 2013). Results from this study illustrate that goals related to water resource issues are frequently assigned a high priority for TCU teaching, research, and outreach initiatives. Unfortunately, the Salish Kootenai College currently is the only TCU in the United States that offers students a four-year bachelor's degree program in hydrologic sciences. Access to the financial resources necessary for TCUs to expand existing or offer new programs in hydrologic science and related STEM fields is critical to meet the growing needs of indigenous communities in adapting to climate change.

Aside from *building the climate adaptive capacity of indigenous peoples*, *food sovereignty and adaptive agriculture* was the most frequently identified priority goal to support adaptation on reservation lands. Nearly half of participants mentioned this as their *additional* top priority. This may suggest that TCU administrators, faculty, and students are most concerned with the impacts of climate change on the physical well-being of indigenous communities as expressed in their ability to access quality foods on reservations. In particular, TCUs located in semi-arid environments reported *food sovereignty and adaptive agriculture* more frequently (62.5%) than did participants located in arid (43.8%) and non-arid (38.5%) environments.

The issue of tribal food security and sovereignty dates back to the creation of reservations during the nineteenth century. While many indigenous communities on reservation lands have experienced historical and contemporary challenges in accessing fresh, nutritious foods, climate change will likely exacerbate this struggle. On the Navajo Nation, recent outreach programs to expand home and school gardens have been linked to healthier lifestyles as demonstrated by community members (Lombard et al. 2014). In this arid environment, access to water resources to sustain these practices in the future, due to rising temperatures and increasing drought aridity of these lands, may pose significant barriers to adaptation efforts to ensure food sovereignty. Because self-sufficient, small-scale agriculture is a traditional practice for many tribes, including the Hopi and Pueblo tribes, communities in the southwestern United States, for example, may promote sustainable agriculture practices as their top priority to enhance climate resiliency.

In other areas where cultural sustenance practices relate primarily to hunting, fishing, and gathering practices, promoting crop and/or animal husbandry agriculture to ensure food sovereignty may not be as widely accepted. Instead, concerns about food sovereignty in the face of climate change may relate more directly to ecological health. This may contribute to the different responses pertaining to *ecological interactions and services,* where 46.2% of the responses represented TCUs located in non-arid environments as compared to respondents located in arid (18.8%) and semi-arid (31.3%) environments. For example, for the members of the Swinomish Nation located

in the Pacific Northwest, where fish comprise the primary traditional food, continued access to fishing grounds not only guarantees their nutrition but demonstrates their cultural resilience as well (Donatuto et al. 2011).

The Equity in Educational Land-Grant Status Act of 1994 authorized the U.S. Congress to assign land-grant status to TCUs. The United States Department of Agriculture National Institute of Food and Agriculture (USDA NIFA) provides annual funding to TCUs to diversify agriculture and land-use programs (Baird 1996). Early education programs, which began with $50,000 'equity grants' awarded in 1996, stemmed from locally identified needs of reservation communities on which these institutions are located (Young 1996). Expanding funding to support and expand these ongoing programs could help build the capacity of TCUs to support tribal adaptation to climate threats to food and agriculture.

Conclusion

There are many challenges in assessing the needs and priorities of TCUs, such as their remote locations and the lack of baseline data. This study offers exploratory methods to pursue these research objectives as they relate to climate adaptation initiatives on tribal lands. Future research to explore these priorities further should examine the depth, breadth, rigor, and variance of TCUs' existing STEM and related climate science curricula. A review of existing curricula may help to inform development of new curricula and enrich existing curricula aimed at preparing future tribal leaders to refine, implement, and objectively evaluate climate adaptation initiatives unique to their reservation communities. Future research should also investigate additional topics impacting the ability of tribes to adapt to a changing climate. These topics include reservation land tenure issues, water right entitlements and settlements, economic dependency on natural resources, and other environmental and ecological impacts to tribal economies, livelihoods, and quality of life. Multi-disciplinary research approaches are necessary to assess the full breadth of these issues affecting the capacity of indigenous communities to adapt to climate change impacts on tribal lands.

Our study suggests that promoting tribal climate adaptation on reservation lands is a priority at TCUs. The results reveal several specific topics that are of the highest concern to TCU faculty, administrators, and students, such as creating or expanding food-sovereignty programs and exploring climate impacts to water resources. In each analysis of our survey data, however, concerns about fiscal constraints and the capacity of TCUs to contribute to tribal climate adaptation needs rose to the top priority.

Given the potential for TCUs to work collaboratively with indigenous communities to promote climate resiliency, addressing these priority needs could prove to be extremely beneficial for the indigenous communities that TCUs serve. A recent economic report suggests that TCUs contribute to the United States economy with notable returns on investments (American Indian Higher Education Consortium 2015). In 2009, TCUs added an estimated 76.2 million to the economy of Montana, the only state with fully accredited TCUs on each Native American reservation (Stockwell 2016). Increased federal funding allocated directly to TCUs is long overdue and essential to strengthening the long-term path for TCU sustainability and expansion.

The path forward for indigenous communities under current threats of climate change is much like their respective paths that epitomize a history of survival. In fact, tribes have a long and rich climate adaptation history that includes creating new technologies, applying traditional ecological knowledge, adopting diverse food resources, and even undergoing short and long-term migrations (Gautam et al. 2013). These examples illustrate the timeless environmental and cultural resiliency of indigenous people. Indigenous communities are more likely to foster innovative solutions to climate-induced impacts on water resources when tribal, federal, and TCU leaders work together to better understand and support community identified adaptation priorities and needs.

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