Re-evaluation of sugarcane borer (Lepidoptera: Crambidae) bioeconomics in Louisiana


USDA-ARS, Sugarcane Research Laboratory, Southern Regional Research Center, 5883 USDA Road, Houma, LA 70360, USA

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A B S T R A C T

The sugarcane borer, Diatraea saccharalis (F.) (Lepidoptera: Crambidae), is the key insect pest of sugarcane, Saccharum spp., grown in Louisiana. For more than 40 years, Louisiana sugarcane farmers have used a value of 10% internodes bored at harvest as the economic injury level (EIL). Three plant-cane studies were conducted to re-evaluate the long-standing sugarcane borer EIL level using the most recently released varieties of sugarcane. Varieties were exposed to artificially enhanced borer infestations; the experimental treatments consisted of borer control with insecticides or no control. Data were collected on infestation intensity, damage intensity, and associated yield losses. Crop yields from plots were obtained by mechanical harvesting, and losses were classified as field losses, e.g., losses of gross tonnage in the field and factory losses, e.g., losses that were realized at the factory as cane is being milled. Farm income is based on the product of these two measures of yield, i.e., cane yield \times sugar yield. In our study, seasonal stalk-infestation counts did not reveal any indication of preference by the borer moths for a specific variety; infestation pressure was generally uniform within a season among the varieties that we planted. Significant differences were detected among the varieties for harvest percentage of internodes bored as well as yields between borer-controlled and non-controlled plots (\textit{P} < 0.05). In general, varieties were less susceptible to losses in the field (sugarcane yields) than in the factory (sugar yields). As a group, the most recent varieties released to Louisiana growers exhibit more tolerance to the borer than varieties grown 40 years ago. The percent reduction in sugar/ha loss per 1\% internodes bored has decreased from an average of 0.74 for varieties grown in the 1960s to 0.61 as a mean for the newly released varieties. Although the cost associated with an insecticide application for sugarcane borer control has increased nearly 4-fold from 1971 to present, sugar yields have increased by approximately 60\% allowing farmers to offset some of these increased costs. Our economic analysis indicates that the EIL of 10\% internodes bored is too high, considering the high yielding potential and susceptibility of currently grown varieties. For the most at risk farmer, the tenant farmer, a more appropriate value for the EIL is 6\% internodes bored. However, this EIL can be raised 12\% if a resistant variety is grown.

1. Introduction

Damage caused by larvae of the sugarcane borer, Diatraea saccharalis (F.) (Lepidoptera: Crambidae), continues to be an important source of yield loss incurred by Louisiana sugarcane (interspecific hybrids of Saccharum spp.) farmers (Reagan, 2001). Likewise, the costs associated with insecticide applications to minimize these losses represent a significant input by farmers (Salassi and Deliberto, 2007). When these monetary costs are coupled with the social/political ‘costs’ associated with widespread aerial applications of insecticides and with concerns for the possibility of resistance to currently recommended insecticides, it is clear that farmers must practice judicious use of insecticides if they are to continue to have this important control tool.

Growing varieties with resistance to the borer has been recommended for many years and is an important component of the current integrated pest management program (Reagan and Martin, 1989). The benefits of growing borer-resistant varieties are realized both on the farm in reduced insecticide usage and, on an area-wide basis, by possibly reducing area-wide borer pressure (Bessin et al., 1990). However, the release of resistant varieties to farmers remains intermittent, and when a new variety is first released little is known, beyond limited comparisons of the percent internodes bored, about how the variety will react to the borer when grown commercially. The management of borers on
newly released varieties is generally based upon the personal experience of farmers and their crop consultants. This process can take several years, and only after a new variety has been increased to the point that it is being grown on a significant area do farmers become confident in how to manage it. If farmers are to more effectively manage new varieties, and thus optimize chemical control, information on anticipated sugarcane borer infestation intensity and resulting yield losses must be available as near to the variety’s release as possible. Forming the basis of assessment and decision making is bioeconomics, the study of the relationships between pest numbers, host responses to injury, and economic losses (Pedigo, 1996).

Metcalfe (1969), in his thorough examination of yield loss caused by sugarcane moth borers, identifies procedures for direct estimation of losses and for an estimation of damage and its correlation with loss. One approach to directly estimate loss, both field loss (= loss of weight) and factory loss (= effect on sucrose content and recovery), is to compare yields of infested and non-infested stands of sugarcane from different plots or fields, or in different years. As with direct measures of loss, Metcalfe also discusses methods of sampling fields and expressing damage quantitatively as ‘levels of infestation’. The author suggests the possibility of using these indirect measures as ‘indices of loss’, which may be defined as any counts or measurements related to loss of the final product, sugar.

One of the most commonly used methods for measuring intensity of infestation is determining percentage of internodes bored (penetrated) by larvae. Bored internodes are identified by a distinct entry hole. Metcalfe (1969) reported that percentage of internodes bored is the only index of intensity of infestation that has been correlated with yield loss, more particularly with loss of sucrose in the cane. Milligan et al. (2003), while developing indices for selection for borer resistance, also found that the most effective single trait to indicate yield loss is percentage of internodes bored.

Determining yield losses associated with sugarcane borer injury can be complicated by several factors. First, damage is accumulated over an extended period of time, at least 3 months in Louisiana. The period when economic damage begins to occur is approximately the second week of June when the first above-ground internodes are formed and usually ends in the second week of September (Pollet et al., 1996). Sometimes this critical period may extend longer. Second, when insect damage occurs during that period of formation of above-ground internodes is important. Early internodes contribute more to overall sucrose yields than internodes formed later (Fernandes and Benda, 1985). Therefore, varieties can tolerate increasingly greater infestations as the season progresses. Thirdly, the method of determining sucrose yields can influence estimates of yield losses. Methods of sucrose determination that do not include increases in fiber are likely to underestimate the impact of sugarcane borer feeding (White and Hensley, 1987).

Early work in Louisiana on economic loss associated with borer damage showed a loss factor of 0.74% sugar/ha for each 1% internodes bored (Mathis et al., 1960). With this relationship as a basis for calculating an economic injury level (EIL), farmers in Louisiana have long accepted borer damage up to 10% internodes bored at harvest.

To avoid damage exceeding the 10% EIL, a weekly scouting program is performed (Pollet et al., 1996) and only infestations exceeding the economic threshold (ET) of 5% infested stalks are treated with insecticides. Stern et al. (1959) defined ET as “the population density at which control action should be determined (initiated) to prevent an increasing pest population (injury) from reaching the economic injury level.” However, the problem in estimating ET is to be able to translate percent plants infested when fields are scouted into probable percentage internodes bored at harvest. The factors that could affect the relationship between stalks infested at survey and internodes bored at harvest are numerous and unpredictable. For this reason, the ET in Louisiana is more of a subjective one and can be referred to as a nominal threshold as defined by Poston et al. (1983).

As farmers seek to become more efficient in their operations to improve their profit margins, it will become increasingly important that they have EIL estimates on varieties as they are released. These estimates should be determined in a manner that reflects as near as possible on farm-harvesting procedures and factory-quality measurements with losses evaluated under current economic conditions. We initiated this study to evaluate a group of the most recently released Louisiana sugarcane varieties to sugarcane borer feeding. Data were collected that relate season-long borer infestations to harvest damage indices, and ultimately to associated yield losses. These data were then subjected to an economic evaluation using current costs and sugar prices in order to assess the applicability of the long-standing EIL to current varieties.

2. Materials and methods

A series of three plant-cane experiments were conducted yearly beginning in 2003 and ending in 2005 to evaluate newly released and soon to be released sugarcane varieties to season-long infestations of the sugarcane borer. Each year, new experimental sugarcane varieties are planted at the USDA-ARS-SRRC Sugarcane Research Laboratory’s Ardoyne Research Farm near Schriever, LA, for evaluation under artificially enhanced sugarcane borer infestations. These evaluations are part of a variety program conducted jointly by the USDA-ARS, the Louisiana State University Agricultural Center, and the American Sugar Cane League of the USA. The experimental variety portfolio changes from year to year as existing varieties are dropped out of the program and new varieties are added. For this report, only the five experimental varieties planted in all 3 years from 2003 to 2005 were included in the analysis of data. These varieties were Ho 95-988, HoCP 96-540, L 97-128, L 99-226, and L 99-233. The commercial standard HoCP 85-845 (Legendre et al., 1994) was included as the borer-resistant standard. All of the varieties were ultimately released to farmers (Anonymous, 2004, 2006a,b; Tew et al., 2005a,b).

Test varieties were planted in three-row plots 4.9 m long with a 1.8 m inter-row spacing and with a 1.2 m alley between plots. The experimental design was a split-plot with four replications. Insecticide was applied to the tested plots with a CO2-pressurized backpack sprayer calibrated to deliver 931/ha at 240 kPa every 3 weeks beginning the second week of June and ending the second week of September. The spray boom was a single nozzle oriented to spray a 91 cm band of the insecticide spray solution to the canopy whorl. The insecticide tebufenozide (Dow AgroSciences, Indianapolis, IN) was applied at the rate of 438 ml/ha with a non-ionic surfactant (Latron CS-7, DowAgroSciences) at 0.25% (vol:vol). Subplots were varieties and were assigned within each main plot replication as a randomized complete block design.

Standard Louisiana sugarcane cultural practices were followed during each cropping season (Legendre, 2001), with the following exceptions. First, a single row of maize (Zea mays L.) was intercropped between each three-row plot. Maize served as an inoculated host for enhancing borer populations and increasing uniformity of infestations. Procedures for infesting corn are outlined by White et al. (1996). The maize on these rows was
removed after one generation of borer had cycled in the maize (approximately 30 days), and the resulting bare rows were maintained weed-free. Second, native infestations of the red imported fire ant, Solenopsis invicta Buren, were suppressed with a mixture of two insecticidal baits. A mixture of methoprene (Wellmark International, Schaumberg, IL) and hydramethylnon (BASF, Research Triangle Park, NC), at 1.1 kg/ha each, was applied by an all-terrain vehicle-mounted cyclone spreader (Herd Seeder Co. Inc., Logansport, IN) on the following dates: 16 July 2003, 6 May 2004, and 4 May 2005. Suppression of fire ants is necessary since they are effective predators of all immature stages of the sugarcane borer and therefore capable of reducing infestation levels and increasing patchiness of infestations.

Beginning the second week of June, weekly infestation counts were performed in each non-treated plot. Counts were taken from 10 stalks randomly selected from a single row in each plot. The rows surveyed were alternated each week so that each row in a plot was sampled every fourth week. Stalks were sampled in situ and left intact. Only 2–3 leaf sheaths of the upper one-third of the stalk were surveyed which was accomplished by carefully pulling leaf sheaths away from stalks and examining behind the sheaths and the surface of the associated internodes for the presence of borer larvae. Internodes from this region of the stalk are considered target internodes because they are the primary sites of larval entry into the stalk (White, 1993). Sampling in this manner approximates survey techniques employed by crop consultants.

Prior to harvest (from mid- to late-August) counts of mature stalks were made in all plots. At this time, stalk height measurements were also taken from 15 stalks (5 stalks × 3 rows) in each plot. For these measurements, height from the row top to the top-visible dewlap was recorded. Although stalk measurements taken at this time was somewhat premature, waiting until later in the season would have increased the risk of encountering lodged cane making it impossible to accurately count or measure.

At harvest, 15 stalks (5 stalks × 3 rows) were collected at random from each plot and returned to the laboratory. Stalks were then stripped of leaves and leaf sheaths and topped at the last fully expanded internode. The total number of internodes and the number of internodes damaged by sugarcane borer larvae were noted for each stalk. Cane remaining in the field was machine harvested with a Cameco 3500 (John Deere Thibodaux, Thibodaux, LA) single-row chopper harvester. Cane harvested from each row was collected in a weigh wagon equipped with load cells to determine the weight of harvested cane. A subsample of billets (∼5 kg) was collected from the cane stream as it entered the weigh wagon from the harvester’s conveyor from each row of each plot. This cane was collected in burlap sacks and taken to the laboratory for processing.

A 19-l bucket was filled with equal portions of cane from each of the three billet subsamples taken from each row of a three-row plot. Cane billets were then chipped using a pre-breaker (a set of hydraulically driven rotating blades). A 1000-g sample of this shredded cane was placed in a hydraulic press for 2 min at 21 MPa to extract juice for sucrose analysis. The resulting fiber was weighed and placed in a dryer for a minimum of 48 h at 66 °C to remove moisture. Sucrose determination was based on procedures by Legendre (1992).

Data were analyzed via analysis of variance with SAS 8.2 (SAS, 2001) software using PROC GLM with specified error terms as described in McIntosh (1983) with year as a random variable and replications nested within year. Means of significant effects were separated using Fisher’s protected LSD at $p \leq 0.05$. Due to a significant variety by insecticide treatment interaction, data were then reanalyzed taking into account this interaction in order to better interpret varietal differences.

3. Results and discussion

Although intensities and patterns of infestation varied from year to year, some consistencies were observed. First, within each year, little differences existed among varieties in their seasonal infestation levels (Fig. 1). In the free-choice test provided by this experiment, moths did not appear to discriminate among varieties since infestation pressure was generally uniform among the test varieties. A notable exception was in 2004 and 2005 when L97-128 appeared to be preferred by female moths early in the season. This variety is known for its early emergence in the spring followed by rapid growth. This growth habit may attract moths to this variety when in a choice test. However, this difference in preference was not seen later in the season. Secondly, there was a general decline in infestation intensity as the season progressed.

A combined analysis of variance of yield and the components of yield, as well as damage by borer larvae, are shown in Table 1. Some significant two-factor interactions were detected, but no three-factor interactions were found following analysis of variance. Significant interactions involved agronomic traits (i.e. sucrose and stalk number) and probably reflect the vagaries of yield caused by variations in seasonal growing conditions. An
important exception was percent internodes bored that was associated with a highly significant variety × treatment interaction. This important interaction indicates that varieties responded differently to the two levels of borer pressure, i.e. treated and non-treated. Most of the response variables were significant for the two main effects: variety and treatment.

An average of the 3 years of bored internodes data from non-treated plots revealed three distinct groupings for the six varieties—a highly susceptible variety (Ho 95-988), an intermediate group (L 99-233, L 97-128, HoCP 96-540), and a resistant group (HoCP 85-845, L 99-226, L 99-233) (Fig. 2). It is interesting to note that the two resistant varieties sustained damage at a level near the traditional 10% EIL when no insecticides were applied.

**Fig. 2.** Mean percentage of 3 years of bored internodes data for six sugarcane varieties. Means followed by the same letter are not significantly different (P < 0.05, least significant difference).

Fig. 3 summarizes the difference between insecticide-treated and non-treated plots for each variety, averaged across the 3 years of the study for the major components of yield loss—losses both for field and factory. Tonnes of cane per ha is the principle yield component reflecting field loss, and in our study we found significant losses between treated and non-treated plots only for the varieties HoCP 96-540 and L 99-233. Purity and theoretical recoverable sugar (TRS) are measures of juice and cane quality and, as such, are measures of factory loss. Feeding by borer larvae significantly reduced values of the two variables measuring factory loss for all varieties we tested except in purity for the varieties HoCP 96-540 and L 99-226. Sugar per ha is the product of TRS and cane yields, and is the yield variable that is utilized to derive farmer payments. All the varieties in our study, except L 99-226, sustained significantly reduced sugar yields due to unabated borer feeding in the non-treated plots.

Our findings have important implications from a pest management perspective as they suggest that variety-specific EILs and ETs are appropriate. Posey et al. (2006) showed that susceptible varieties justify a lower infestation threshold than more resistant varieties to achieve adequate injury reduction. However, there are many factors beyond variety effects (e.g. predation and weather) that determine whether stalks with infested leaf sheaths actually become internodes bored at harvest and what yield loss might be expected from those damaged internodes. Unfortunately, many of these factors, such as differences in growing and harvesting conditions, vary from year to year and are unpredictable.

Therefore, the decision to treat or not is now and probably will continue to be subjectively based primarily upon judgment and experience. Attitudes of individual farmers (and their consultants) towards sugarcane borer control are also important, e.g. their sensitivity to differential infestation levels vs. crop yield loss, cost of insecticidal control vs. sugar price. These attitudes can influence the amount of infestation tolerated and related damage thresholds. Hence, knowledge of how individual varieties react to borer feeding and how the borer reacts to the variety can be very beneficial to farmers and their crop consultants as they attempt to make appropriate decisions on the use of insecticides.

**Fig. 4** summarizes the relationship of mean seasonal infested stalks to mean percent internodes bored at harvest in the non-treated plots and to mean percent loss in sugar/ha. These are important relationships as they reflect biological processes and are measures of the effectiveness of pest management decisions required during the growing season. We found a 3-year mean seasonal stalk infestation of 21% (from 17% to 25%). In a free-choice test, our data indicate little difference among varieties in the level of season-long insect pressure. However, there were large differences among varieties in the success of a borer larva entering the stalk. The mean harvest bored internode value for the 3 years of our study was 18% (from 11% to 31%). This level of damage resulted in a mean loss of sugar/ha of 11% (from 3% to 15%). There were differences among the cultivars in the amount of sugar loss per 1% bored internodes. One group included the varieties Ho 95-988, classified as susceptible by bored internode counts, L 97-128 classified as intermediate, and the cultivar L 99-226 classified as resistant (**Fig. 2**). This group is tolerant to borer feeding as the ratio of percent loss in sugar/ha per 1% internodes bored was 0.5 or less.

The second group, a group made up of the varieties L 99-233 (intermediate), HoCP 96-540 (intermediate), and HoCP 85-845 (resistant), is less tolerant to borer feeding as the ratio between damage and sugar loss for these cultivars ranged from 0.7 to 0.8. We were surprised that the resistant standard HoCP 85-845 is significantly different.

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**Table 1**

Statistical analysis of D. saccharalis injury, sugarcane yield components, and fiber content in 2003–2005 of selected sugarcane varieties grown in Houma, LA.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variety (V)</th>
<th>Treatment (T)</th>
<th>V × T</th>
<th>V × year</th>
<th>T × year</th>
<th>V × T × year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F P &gt; F</td>
<td>F P &gt; F</td>
<td>F P &gt; F</td>
<td>F P &gt; F</td>
<td>F P &gt; F</td>
<td>F P &gt; F</td>
</tr>
<tr>
<td>Percent bored internodes</td>
<td>16.7</td>
<td>0.0001</td>
<td>519.3</td>
<td>0.0001</td>
<td>13.1</td>
<td>0.0001</td>
</tr>
<tr>
<td>Sugar yield</td>
<td>25.5</td>
<td>0.0001</td>
<td>37.6</td>
<td>0.0001</td>
<td>1.09</td>
<td>0.3701</td>
</tr>
<tr>
<td>Cane yield</td>
<td>11.3</td>
<td>0.0001</td>
<td>3.08</td>
<td>0.0824</td>
<td>0.82</td>
<td>0.5404</td>
</tr>
<tr>
<td>Sucrose level</td>
<td>22.1</td>
<td>0.0001</td>
<td>92.0</td>
<td>0.0001</td>
<td>0.99</td>
<td>0.4304</td>
</tr>
<tr>
<td>Brix</td>
<td>51.3</td>
<td>0.0001</td>
<td>95.3</td>
<td>0.0001</td>
<td>0.64</td>
<td>0.6661</td>
</tr>
<tr>
<td>Fiber</td>
<td>9.30</td>
<td>0.0001</td>
<td>0.89</td>
<td>0.3474</td>
<td>0.14</td>
<td>0.9836</td>
</tr>
<tr>
<td>Purity</td>
<td>14.6</td>
<td>0.0001</td>
<td>39.6</td>
<td>0.0001</td>
<td>1.81</td>
<td>0.1174</td>
</tr>
<tr>
<td>Stalk weight</td>
<td>54.2</td>
<td>0.0001</td>
<td>3.1</td>
<td>0.0860</td>
<td>0.97</td>
<td>0.4477</td>
</tr>
<tr>
<td>Stalk height</td>
<td>44.1</td>
<td>0.0001</td>
<td>33.5</td>
<td>0.0001</td>
<td>1.05</td>
<td>0.3928</td>
</tr>
</tbody>
</table>

* Statistical analysis conducted using SAS PROC MIXED with all variables fixed.
included in this group as earlier yield loss estimates suggested that this variety could tolerate borer feeding. This finding illustrates the difficulties in obtaining sound estimates of yield losses associated with sugarcane borer feeding as growing and harvesting conditions vary greatly from year to year; thus, causing difficulty in establishing variety specific EILs and ETs.

Using the damage and yield loss estimates from Fig. 4, we can calculate an average percent loss of sugar/ha for each 1% internodes bored of 0.61 (11%/18%). This value is lower (27% lower) than the 0.74 reported earlier in Louisiana and probably reflects differences in the yield potential of varieties currently being grown, given the greater tolerance to borer feeding expressed by these varieties. Varieties currently being grown have much greater yield potential than those being grown in 1971. In 1971, Louisiana sugar yield averaged 4250 kg sugar/ha, while the 4-year average yield from 2003–2006 is 6760 kg sugar/ha—a 60% increase in sugar yields.

Just as yields have increased substantially during the last 35 years, the cost of insect control has also increased substantially with changes in insecticide chemistry options available to farmers. In 1971, the cost (including application fee) of making a single application of azinphosmethyl was $11/ha (Hensley, 1971), while the cost in 2007 of a single application of tebufenozide is $45/ha (Salassi and Deliberto, 2007). This represents a 4-fold increase in the cost of control.

Using our value of 0.61 as an average estimate of sugar loss/ha for each 1% bored internodes, we calculated the EIL using the following formula:

Percent internodes bored (EIL) = Cost of control
                             \( \frac{\text{market value}}{\text{damage per unit injury}} \)

\[
\text{Percent internodes bored (EIL)} = \frac{\text{Cost of control}}{\text{market value} \times \text{damage per unit injury}}
\]

Fig. 3. Three-year mean difference between treated (■) and non-treated (□) plots for the major components of yield for six sugarcane cultivars (P<0.05) (2003–2005). The asterisk denotes a significant difference between the treated plots and the untreated plots (Fisher’s protected LSD, P<0.05).

Fig. 4. Comparison of 3-year means among six sugarcane cultivars for mean seasonal percent infested stalks (■), percent internodes bored (□), and percent loss in sugar yields (■) (2003–2005).
Percent internodes bored (EIL)
\[
\text{EIL} = \frac{\text{Market value adjusted to account for } 40\% \text{ take by mill and } 17\% \text{ take by landlord)}
\]
\[
\times (8.25 \text{ kg/ha loss per } 1\% \text{ internodes bored})
\]
\[
\times (41.23 \text{ kg/ha loss per } 1\% \text{ internodes bored})
\]
\[
= 5.8\% \text{ internodes bored}
\]
This value is roughly 40% lower than the long-accepted EIL of 10% internodes bored. Growing varieties more resistant to the borer provide the means to raising EIL and ultimately increasing farmer profits. Varieties like L 99-226 are particularly attractive to farmers as it was shown to lose only 0.30% reduction in sugar/ha for every 1% internodes bored (Fig. 4). This variety would be of particular interest to the tenant farmer as the EIL for this sugarcane would be 12%.

Growing susceptible varieties with a high yield potential may allow farmers to ignore sugarcane borer damage. We have shown that the variety Ho 95-988 appears to be highly susceptible to the borer; however, even with a 3-year mean of over 30% bored internodes, its yields were comparable to four of the varieties we tested (HoCP 85-845, HoCP 96-540, L 97-128, and L 99-223) with season-long control (Fig. 3). However, if not carefully monitored, sugarcane borer infestations in these varieties can reach devastating levels. Also, a strategy of growing borer-susceptible varieties can have implications from an area-wide perspective by possibly increasing the overall borer pressure. Our current study did not address these implications; however, the susceptible cultivar LCP 85-384 at its peak comprised 91% of Louisiana’s total area planted (Legendre and Gravois, 2005) with sugarcane and the frequency of spraying did not increase commensurately (D.K. Pollet, personal communication). This suggests that on a year-long basis other factors, such as weather and beneficial arthropods, may overwhelm any area-wide impact that a sugarcane variety may have.

In summary, it will continue to remain up to the individual farmer to make the informed management decisions needed to maximize profits. It is therefore important that each newly released variety be thoroughly evaluated to provide information on anticipated infestation intensities, damage levels, and yield losses so that effective management decisions can be made. Variety-specific information will allow the farmer to implement integrated pest management and insecticide resistance management practices, as well as manage the social/political ‘costs’ by planting resistant varieties in those areas that are prohibited or impractical for spraying i.e. near schools, hospitals, and habitations.

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References