Effect of Soil Management Practices on the Sweeping Operation during Coffee Harvest

Tiago de Oliveira Tavares, Matheus Anan de Paula Borba, Bruno Rocca de Oliveira, Rouverson Pereira da Silva,* Murilo Aparecido Voltarelli, and Antônio Tassio Santana Ormond

ABSTRACT
The mechanical sweeping and picking of coffee berries are necessary to recover berries that naturally fall on the soil during the mechanical harvesting process. The soil characteristics and the materials that are collected affect these two operations; in addition, there are reports that suggest that mechanical sweeping and picking are hampered by subsoiling. In this regard, the current study evaluated losses during the mechanical sweeping and picking of coffee cultivated under four soil management treatments in Presidente Olegário, MG, Brazil. The four treatments consisted of the following soil management practices: subsoiling and crushing; subsoiling and harrowing; subsoiling followed by harrowing and crushing; and the control, with no soil management. The soil was prepared in 2014, while the coffee sweeping and picking occurred in 2015 and 2016. The experimental design followed the assumptions of statistical process control, and fifteen points were evaluated per treatment in accordance with the statistical process control guidelines. The lowest loss rates were obtained for the subsoiling and crushing soil management treatment, whereas harrowing after subsoiling led to the highest losses and the lowest process quality.

Core Ideas
• The harvest performance can be affected by plant phenological behavior, non-uniform fruit ripening, late harvest, pests and diseases, rods vibration intensity, displacement velocity and, finally, slope. After harvesting, the approximately 10–20% of coffee cherries that fall on the ground are known as the sweeping coffee and require a gathering operation.
• The mechanical sweeping and gathering allow higher operational capacity (working greater areas in shorter times), thus increasing profitability and reducing operational costs, however, these machines are sensitive to oscillation and/or soil topography (Tavares et al., 2015). In addition to this limiting factor, one of the main obstacles to the mechanical picking of sweeping coffee is the subsoiling operation that consists of unpacking the soil by moving the soil surface of the coffee plantation areas where coffee berries are going to be harvested later (Fernandes et al., 2012). Commonly practiced in coffee cultivation, subsoiling consists of breaking the compacted soil layer to improve the plant water and nutrient uptake rates; it also increases the unevenness of the soil surface (Fernandes et al., 2012). Soil topography plays a big role in mechanical harvesting, since uneven soil surfaces promote fruit losses and reduce the cleaning efficiency of mechanical pickers, resulting in an increased soil volume transported with the coffee berries (Tavares, 2016).

To ensure that the best quality of cleaning is promoted by coffee berry pickers, the statistical process control (SPC) method is a fundamental tool for quality control during the stages of this agricultural process. The SPC graphically expresses results in a sequential manner, allowing average behavior, stability and variability levels to be verified throughout the operation (Silva et al., 2008). An important complementary tool of SPC is capacity analysis; this tool uses statistical means to calculate how much a given process can stay within the quality levels determined by the manager (Montgomery and Runger, 2003).

doi:10.2134/agronj2017.10.0598
Available freely online through the author-supported open access option
Copyright © 2018 by the American Society of Agronomy
5585 Guilford Road, Madison, WI 53711 USA
This is an open access article distributed under the CC BY license (https://creativecommons.org/licenses/by/4.0/)

*Corresponding author (rouverson@gmail.com).

Abbreviations: HC, harvesting losses; IAC, Instituto Agronômico de Campinas; I-MR, individual charts-moving range; LCL, lower control limits; LSL, lower specific limit; Pp, general capacity; PTO, power take-off; SC, subsoiler and crusher; SH, subsoiler and harrow; SHC, subsoiler, harrow, and crusher; SPC, statistical process control; UCL, upper control limits.
In this context and with the assumption that soil management can affect the losses during and economic viability of the mechanical picking of sweeping coffee, this study used SPC tools to investigate whether four different soil management treatments could reduce losses and costs during the sweeping and mechanical picking of fallen coffee.

**MATERIALS AND METHODS**

The experiment was conducted in an agricultural area of Presidente Olegário, Minas Gerais, Brazil, located at 18°02′04″ S and 47°27′38″ W, with an average elevation of 917 m and a 3% slope. The soil was classified as medium texture, and the climate was classified as an Aw type according to Köppen (Peel et al., 2007). The area had a 1400 mm average annual precipitation value.

The cultivar Catuai Red IAC 144 coffee was transplanted in December 2005, with 4.0 m spacing between rows and 0.5 m between plants. The experiment lasted from September 2014 to August 2016. The soil management operations were conducted in 2014, while the windrowing, sweeping, and harvesting—picking were conducted during the subsequent 2 yr (2015 and 2016).

The four treatments consisted of the following soil management practices: (i) subsoiler and crusher (SC); (ii) subsoiler and harrow (SH); (iii) subsoiler, harrow and crusher (SHC); and (iv) control, with no soil management. The soil was prepared using a Ykeda subsoiler equipped with a two-rod semi-winged tip, with 2-m spacing between rods and a 0.60 m wide half-wing tip at approximately 0.40 m deep (Ikeda, Marília, Brazil); a Herder crusher, model FLV175 (Herder Implementos e Máquinas Agrícolas LTDA, Matão, Brazil); and a Shengda tandem harrow, model 1BJX-1.7, with a 16” disc at approximately 0.05 m deep (MFRural, Marília, Brazil).

Eleven months after the soil management practices were applied and before the sweeping and picking operations, a 30-m² area was chosen randomly, and one sample was collected per row for all four soil management treatments to determine the amount of coffee cherries on the ground. In the 2015 and 2016 harvests, the areas had the equivalent of 10 and 15 bags of coffee beans per ha⁻¹ on the ground, respectively. Subsequently, mechanical sweeping was performed by a Mogiana windrower and blower, Varre Tudo model (Bertanha, Batatais, Brazil) operated by a 4 × 2 auxiliary front wheel drive John Deere 5425N tractor (John Deere, Montenegro, Brazil) with 55.2 kW (75 hp) power. The tractor worked in first “A” gear at 2400 rpm and at 540 rpm for the PTO (power take-off). The machine had two sweeping discs (windrowers) and two air-directing tubes (blowers). The windrows had vegetal (leaf dust, leaves, and branch fragments) and mineral (soil, rocks, and pebbles) impurities and coffee berries.

The harvest was performed using the Master coffee II picker (John Deere) pulled by the same tractor used in the sweeping, working in first gear at 1700 rpm (540 rpm in the PTO) and a 1.28 km h⁻¹ average operating speed. The picker consists of a pick-up conveyor, drum tracker, set of sieves, turbine and bulk hopper.

After the sweeping and picking, the losses of the two operations were evaluated. To this end, a metal frame with three divisions, a 1.6-m wide central division, which was equivalent to the width of the picker platform, and two 1.05-m lateral bands, one on each side, was used. The frame was placed transverse to the coffee rows. The material in the center of the frame was defined as the harvesting losses, while the material in the lateral bands was characterized as the sweeping losses. The coffee cherries collected at each sampling point were transformed into kg of coffee beans ha⁻¹ using the values determined from the 2014–2015 and 2015–2016 coffee crops. The sweeping and picking losses were calculated by Eqs. [1] and [2]:

\[
SL = \frac{(CRS \times 2500)}{2344}
\]

\[
HL = \frac{(CRP \times 2500)}{2344}
\]

where \( SL \) is the sweeping losses (kg coffee beans ha⁻¹); \( HL \) is the harvesting losses (kg coffee beans ha⁻¹); \( CRS \) is the coffee berries remaining after sweeping (kg m⁻¹); \( CRP \) is the coffee berries remaining after picking (kg m⁻¹); 2500 was the distance traveled by the mechanical set ha⁻¹; and 2344 is the conversion factor from coffee berry to coffee beans.

The experimental design followed the assumptions of SPC (Silva et al., 2015b) with samples collected from the rows at 10-min intervals. For each treatment, 15 samples were collected from the planting row every 15 m, totaling 60 sampling points. The results were analyzed by descriptive statistics using the arithmetic mean, standard deviation, and coefficient of variation. Data normality was checked by the Anderson-Darling test, as recommended by Acock (2008). The coefficient of variation was classified as low (0–10%), medium (11–20%), high (21–30%), and very high (>30%) according to the methodology of Pimentel-Gomes and Garcia (2002).

Next, the sweeping and picking losses and the total loss (sum of the sweeping and picking losses) of the 2014–2015 and 2015–2016 harvests were analyzed using statistical process control (SPC) by building run charts to detect non-random patterns. These non-random patterns allowed the monitoring of the process by the identification and classification of data variations over time. The classification grouped data into four types. For the first type, the mixture pattern had no points near the centerline (mean); successive mixtures of this type indicate that the data associated with the two processes were employed at different levels. For the second type, the grouping pattern was defined by groups of points in an area of the graph indicating variations related to special causes, such as measurement problems. For the third type, the data oscillated between the top and bottom of the chart, and this oscillation pattern indicated that the process was not uniform. For the fourth type, the tendency pattern showed a sustained disinflation in the data, above or below the centerline, indicating that points out of the control range should appear in the near future (Voltarrelli et al., 2015). Dataset values with \( p < 0.05 \) indicate significant, non-random patterns; on the other hand, values with \( p > 0.05 \) are not significant and indicate random behavior of the data, a normal process variation.

The results were also analyzed using individual-moving range charts (1-MR). The upper chart represented the individual values, sampled at each point, while the lower chart was obtained by calculating the amplitude and the difference between two consecutive points. These charts have three lines; the centerline represents the overall mean, while the other two lines are the upper and
lower control limits (UCL and LCL, respectively), calculated based on the standard deviation of the variables. However, in this study, the value 0 was used as the lower specification limit (LSL) (Montgomery, 2009) because there were no negative losses.

Voltarelli et al. (2013) stated that, in general, the purpose of control charts is to detect possible external variations in a process, force process management by creating an improvement plan, and deduce the capacity and limits established for the process. An unstable or out-of-control process can be analyzed or improved by using the 6 Factor Assumption Method, where the six factors are machinery, labor, measurements, methods, materials, and the environment.

Finally, the process capacity was analyzed for indicators whose data met the normality and stability requirements. This analysis was performed using the results (mean and multiples of the standard deviation) of the management without subsoling (control) as the goal and to define acceptable limits. The purpose of this comparison was to verify whether the proposed subsoling treatments could meet the quality level of the control treatment. To this end, a general capacity (Pp) value lower than 1.0 indicated that a process was incapable of meeting the specifications; a value greater than or equal to 1.33 was considered to be adequate and indicative of a capable process that was able to meet the specifications, whereas a value in the 1.0 ≤ p < 1 range was indicative of an acceptable process (Bonilla, 1994).

### RESULTS AND DISCUSSION

The descriptive analysis (Table 1) of the results shows a high standard deviation and coefficient of variation for the sweeping, picking, and total losses in the 2015 and 2016 harvests, except for the total losses in the control, which had no subsoling. In contrast, the standard deviation and coefficient of variation values were higher in the second year than the first year. It was also observed that the control data, without subsoling, had a non-normal distribution for the picking and harvesting operations and total losses in 2015, according to the Anderson Darling test. The other treatments had a normal data distribution for all the quality indicators.

Because the formulas for the capacity analysis had denominators with six multiples of the standard deviation and the losses presented high variability, the acceptable lower and upper control limits were calculated as the mean minus 6σ and plus 6σ, respectively. For negative lower limits, a value of zero was adopted.

For the analysis of the economic management of soil, we used the real costs of operations on the farm in the years 2015 and 2016. To measure the economic returns, we used the coffee prices in the Septembers of the 2 yr.
For the control treatment, the total losses (sweeping and picking) had non-random tendency patterns in 2015, while the harvesting and total losses demonstrated grouping patterns in 2016. The subsoiling, harrowing, and crusher treatments had tendency patterns for the harvesting and total losses (Table 2), which may indicate increased losses during the sweeping and picking process. The other treatments did not have non-random patterns, indicating that the observed variations were completely random and inherent to the processes.

It is important to detect non-random patterns since they indicate unpredictable behavior and variability of the results (Minitab, 2007). However, Voltarelli et al. (2013) suggested that this analysis must be complemented by an individual control and I-MR to verify whether or not factors extrinsic to the process were affecting it. Noronha et al. (2011) stated that process failures may be explained by six factors (machinery, labor, measurements, method, raw materials, and the environment), allowing an assertive intervention by the manager.

The control charts show an average loss during the mechanical sweeping of 67.2 kg ha⁻¹ for the control treatment (no subsoiling) in 2015 (Fig. 1a), which was defined as the target for the other studied soil management treatments. The nearest mean loss, 116.2 kg ha⁻¹, was observed for the subsoiling and crushing (SC) treatment, followed by 130.1 kg ha⁻¹ for the subsoiling, harrowing and crushing (SHC) treatment. The soiling and harrowing (SH) treatment had a loss of 344.1 kg ha⁻¹, which was not only the highest value but also five times greater than the value of the control losses and considered to be a high value for this operation.

The individual control charts for the mechanical sweeping operation show a loss of 129.5 kg ha⁻¹ in 2016 (Fig. 1b) for the control treatment, almost double the loss in the previous year. This result can be explained by the fact that coffee is a biennial plant, so the equivalent of 600 kg and 900 kg of coffee berries were the ground for collection in 2015 and 2016, respectively. In 2016, the lowest loss, approximately 90.3 kg ha⁻¹, was observed for the SC treatment and was very similar to the subsoiling, SHC loss of 90.5 kg ha⁻¹. The loss of 109.2 kg ha⁻¹ obtained for the SH treatment was the closest to the control.

All the values were within the control limits, suggesting that each treatment had a stable process (Fig. 1a and 1b). The level of process instability varied among the different management types. Greater variability was observed for both the SH
management and control treatment. Notably, the results were less variable in 2015 than in 2016, thus indicating that 2015 was characterized by a process of superior quality. In both years, the quality of the mechanical sweeping improved when subsoiling was followed by crushing (SC and SHC).

The moving range control charts show less variability in 2015 (Fig. 1a) than 2016 (Fig. 1b). In both years, the highest variation was observed for the SH treatment since it had the most points that were distant from the mean, indicating a lower intrinsic process quality. It is noteworthy that all analyzed processes were within the UCL and LCL.

Fernandes et al. (2012) highlighted that because subsoiling increases soil roughness, it also increases mechanical sweeping losses, which explains why the best results were obtained after crushing, which more effectively removes the lumps and irregularities caused by subsoiling. Tavares et al. (2015) reported that it is a high-quality preparation method necessary for the performance of pre-harvesting (windowing) to reduce losses and increase the efficiency of the machines. In 2015, the average loss in the mechanical harvesting of the coffee was 59.8 kg ha⁻¹ for the control (non-subsoiling) (Fig. 2a), while average losses of 211.1, 228.9, and 237.8 kg ha⁻¹ were observed for the SH, SC, and SHC treatments, respectively. In this sense, the losses in the treatments were approximately 3.55 to 4.00 times greater than the loss in the control.

The losses during the mechanical harvesting process increased, on average, by 134% and 210% for the SC and control treatments, respectively, in 2016 compared to 2015. This result is attributed to the greater amount of coffee berries that fell and had to be collected between the coffee tree rows in 2016.

Among the management treatments that included subsoiling, the harrowing (SH) and crushing (SC) after subsoiling treatments had low variabilities (better quality of the analyzed process) in 2015 and 2016. On the other hand, the subsoiling, harrowing, and crushing (SHC) treatment was highly variable in both years, which indicates a lower quality process than those of the SH and SC treatments. Moreover, all the management treatments with subsoiling were more variable than the control.

The moving range control charts of Fig. 2b show a greater range (lower quality) compared to that of Fig. 2a; however, the values of both figures were within the control limits.

Silva et al. (2014) stated that the quality of the soil preparation during coffee culturing affects the harvesting process variability,

Fig. 2. Individual control charts and moving range control charts for the mechanical picking losses of the studied soil management practices (2015 and 2016).
which was observed in this work, given the high variations in the harvesting losses for all treatments that included subsoiling compared to the control (without subsoiling). Santinato et al. (2014) emphasized the importance of using better machines to increase the efficiency and quality of mechanical coffee harvesting and reduce losses. It is important to understand the value of mechanical harvesting for the viability of picking the sweeping coffee to conduct positive interventions and improve the quality and efficiency of the process (Santinato et al., 2015).

Figure 3 shows mean total losses (sweeping and harvesting) of 127 kg ha⁻¹ and 256 kg ha⁻¹ in the control (no subsoiling) for the 2015 and 2016 crops, respectively. Compared to the control, in the subsoiling treatments, the losses were 271% higher for the SC treatment in 2015 and up to 437% for the SH treatment in the same year. However, the losses decreased by approximately 116% for the SC treatment and 257% for the SH treatment in 2016. This result can be explained by the more irregular soil–ground between the rows of coffee trees in 2015, which affected the machine performances, after which soil roughness decreased with time, thus increasing the machine efficiency and reducing the losses in 2016.

It was also observed that the process was within the control limits for both charts, except for point 9, which was above the UCL in the moving range chart for the SHC treatment, indicating that this process was unstable in 2015 (Fig. 3a). This out-of-control point probably resulted from a sudden variation in the losses between points 9 and 10. We suggest that this variation can be attributed to soil roughness, an environmental factor, since the machine and evaluation method remained unchanged.

It is known that the capability analysis (Pp) depends on data normality and stability assumptions. Therefore, it was not possible to perform the analysis for the picking and total losses in the control and the total losses in the subsoiling, harrowing and crushing management (SHC) treatment in 2015.

The objective of this study was to determine which of the treatments had losses like those of the control treatment (no subsoiling), which was considered to represent the ideal. Thus, considering the interval between the mean + 6σ (UCL) and 0 (LCL), it was noted that sweeping losses (Table 3) were unlikely to exceed the specified lower limit in all treatments. Nevertheless, 70% of the subsoiling and harrowing management (SH) treatment values were above the acceptable limit in
The first year, while the percentages of the other management types were close to zero. For the SH management treatment, the out-of-control points increased as time passed, since 28.67% of the data were within the acceptable limits in 2015, but this value increased to 98.92% in 2016, indicating the least optimal management treatment. The general capacity (Bonilla, 1994) showed that no subsoiling management treatment reached the stipulated loss levels of the control in the first year, whereas the crusher (SC) and harrowing + crusher (SGC) management treatments were able to meet the required quality standards in 2016.

The picking losses for the treatments with subsoiling did not reach the limits obtained in the control, which suggests the picking operation was much more sensitive to the soil characteristics than the sweeping operation. This observation was reinforced by the percentage of results within the specification limits, which ranged from 26.22% to 34.05% in 2015. In 2016, 2 yr after the soil preparation treatment, the results within the limits increased to 67.08% and 85.44%; however, they were still far from the stipulated ideal level. The SC management treatment yielded the closest results to the specified limits, which indicates that decreasing the revolving of the soil improves the soil capacity to recompose and favors the picking operation. According to Tavares et al. (2015), the picking operation is highly influenced by the windrow characteristics, especially by the concentration of mineral impurities and humidity.

The obtained total loss values showed that the operations were unable to meet the specified limits, a fact explained by the high picking losses contributing to this indicator. The quality of the results evolved over time, varying from 20.40% to 62.28% in the first year and from 75.80% to 90.26% in the second year. Notably, the SC treatment had results that were the closest to the control results.

Fernandes et al. (2012) reported that the subsoiling operation was extremely important for soil maintenance during coffee cultivation since various agricultural operations require machines to travel between crop rows, causing soil densification and negative impacts on plant root development. However, the subsoiling operation caused high losses during the harvesting of the fallen coffee due to the increased roughness of the soil caused by its management. Therefore, strategies to improve soil characteristics are needed to increase the performances of harvesting operations.

A simple economic analysis considering the actual market values of the studied crops and their operation costs was performed. Coffee values (60 kg bags) were negotiated at US$121.32 and US$154.25 for the 2015 and 2016 harvests, respectively. At these values, the initial amount of coffee on the ground was priced at US$1213.20 ha⁻¹ and US$2313.75 ha⁻¹ for 2015 and 2016, respectively, which are considerable amounts that should not be wasted. In the present study, the mechanized operations of crushing, harrowing, sweeping and collecting represented costs of 15.09, 57.44, 29.51, and 58.16 US$ ha⁻¹ yr⁻¹, respectively. These costs were calculated using farm data and that considered the labor, fuel, and maintenance of the machines in the 2015 and 2016 agricultural years.

Therefore, the cost analysis showed that a total amount of coffee worth US$3526.95 could be recovered. The treatment without subsoiling (the control) had a cost of US$175.34 (sweeping and collecting) and loss of US$914.13 (coffee not collected by the machines), which thus produced a return of US$2437.48 (69.11%). For the first subsoiling management

| Table 3. Analysis of the process capacity of the mechanical picking losses in sweeping coffee for different soil management practices. |
|---|---|---|---|
| | Cont† | SC | SH | SHC |
| % Below LSL‡ |
| Sweeping losses | 2015 | 1.97 | 2.03 | 1.33 | 1.36 |
| | 2016 | 0.05 | 0.47 | 1.08 | 0.22 |
| Harvest losses | 2015 | – | 4.69 | 3.57 | 1.26 |
| | 2016 | 3.31 | 4.47 | 6.91 | 1.03 |
| Total losses | 2015 | – | 0.93 | 0.23 | – |
| | 2016 | 0.02 | 2.19 | 3.89 | 0.32 |
| % Above USL§ |
| Sweeping losses | 2015 | 0.00 | 0.50 | 70.00 | 1.69 |
| | 2016 | 0.00 | 0.00 | 0.00 | 0.00 |
| Harvest losses | 2015 | – | 65.56 | 62.38 | 72.52 |
| | 2016 | 0.00 | 10.09 | 21.96 | 31.89 |
| Total losses | 2015 | – | 36.79 | 79.37 | – |
| | 2016 | 0.00 | 7.55 | 20.31 | 23.43 |
| % Within the specifications |
| Sweeping losses | 2015 | 98.03 | 97.47 | 28.67 | 96.95 |
| | 2016 | 99.95 | 99.53 | 98.92 | 99.78 |
| Harvest losses | 2015 | – | 29.75 | 34.05 | 26.22 |
| | 2016 | 96.69 | 85.44 | 71.13 | 67.08 |
| Total losses | 2015 | – | 62.28 | 20.40 | – |
| | 2016 | 99.98 | 90.26 | 75.80 | 76.25 |
| Classification (Bonilla, 1994) |
| Sweeping losses | 2015 | Capable | Incapable | Incapable | Incapable |
| | 2016 | Capable | Capable | Acceptable | Capable |
| Harvest losses | 2015 | – | Incapable | Incapable | Incapable |
| | 2016 | Acceptable | Incapable | Incapable | Incapable |
| Total losses | 2015 | – | Incapable | Incapable | – |
| | 2016 | Capable | Incapable | Incapable | Incapable |

† Cont, control; SC, subsoiling + crusher; SH, subsoiling + harrowing; SHC, subsoiling + harrowing + crusher.
‡ Lower specified limit
§ Upper specified limit.
treatment, the operating cost was US$290.22 (crusher) and the loss was US$1720.51, producing a return of US$1516.22 (48%). The second management treatment cost US$205.52 (harrowing) and had a loss of US$2313.38, generating a return of US$1008.05 (28.6%). Lastly, the third management treatment required an investment of US$320.4 (harrower and crusher) and had a loss of approximately US$2127.56, leaving a return of US$1078.99 (30.59%).

From an economic point of view, the subsoiling operation greatly interferes with the viability of harvesting the fallen coffee on the ground, leading to considerable losses. Among the management types studied, using only the crusher after subsoiling resulted in the best economic result. Notably, it is the management types studied, using only the crusher after subsoiling resulted in the best economic result. Notably, it is important to collect as much fallen coffee as possible from the soil since the coffee beans that remain on the soil become important to collect as much fallen coffee as possible from

The second management treatment cost US$205.52 (harrowing) and had a loss of US$2313.38, generating a return of US$1008.05 (28.6%). Lastly, the third management treatment required an investment of US$320.4 (harrower and crusher) and had a loss of approximately US$2127.56, leaving a return of US$1078.99 (30.59%).

From an economic point of view, the subsoiling operation greatly interferes with the viability of harvesting the fallen coffee on the ground, leading to considerable losses. Among the management types studied, using only the crusher after subsoiling resulted in the best economic result. Notably, it is important to collect as much fallen coffee as possible from the soil since the coffee beans that remain on the soil become important to collect as much fallen coffee as possible from

CONCLUSIONS
After 3 yr, among all the treatments, the crusher management treatment had the lowest losses and best operational quality, with a greater capacity to reduce the losses of mechanical coffee harvesting. The harrow management treatment generated the highest levels of losses and represented an economically undesirable management practice. The operational costs for the handling with crusher management treatment and its associated losses generated the optimal economic result of this study. The statistical control of the process helped enable a better interpretation of the broad results on the operational efficiencies of the machines in this study.

REFERENCES
Acock, A.C. 2008. A gentle introduction to Stata. Stata Press, College Station, TX.